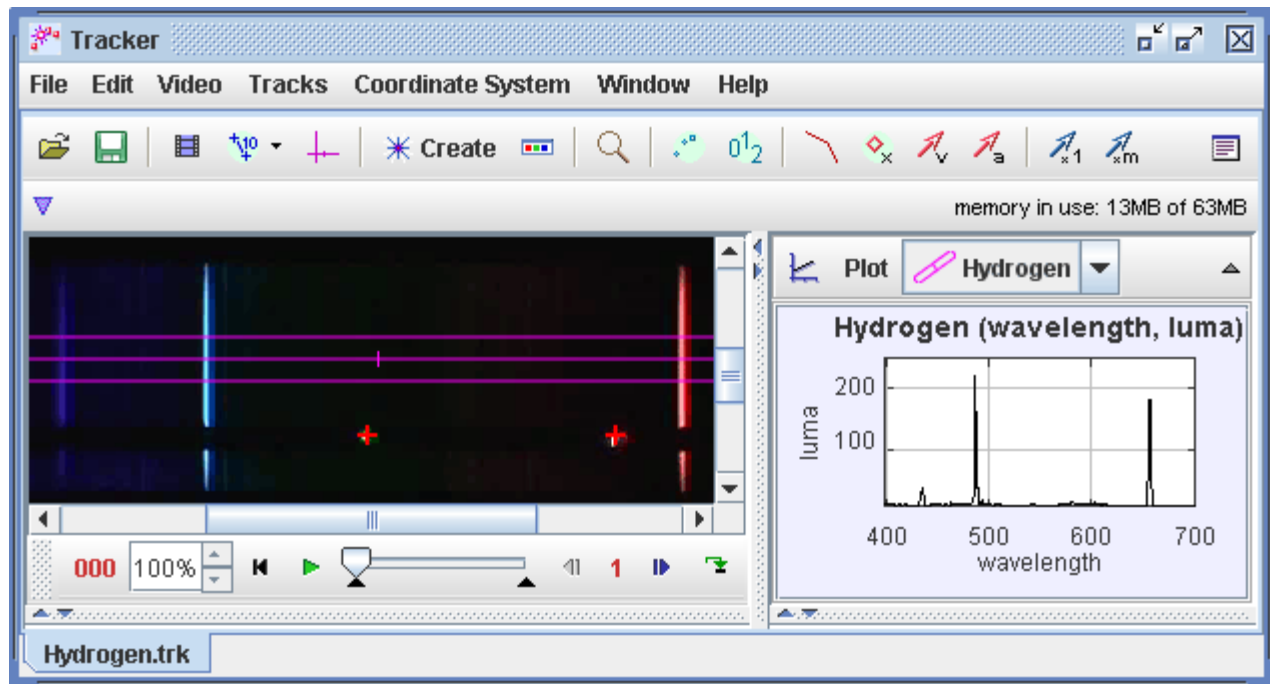


Tracker Help



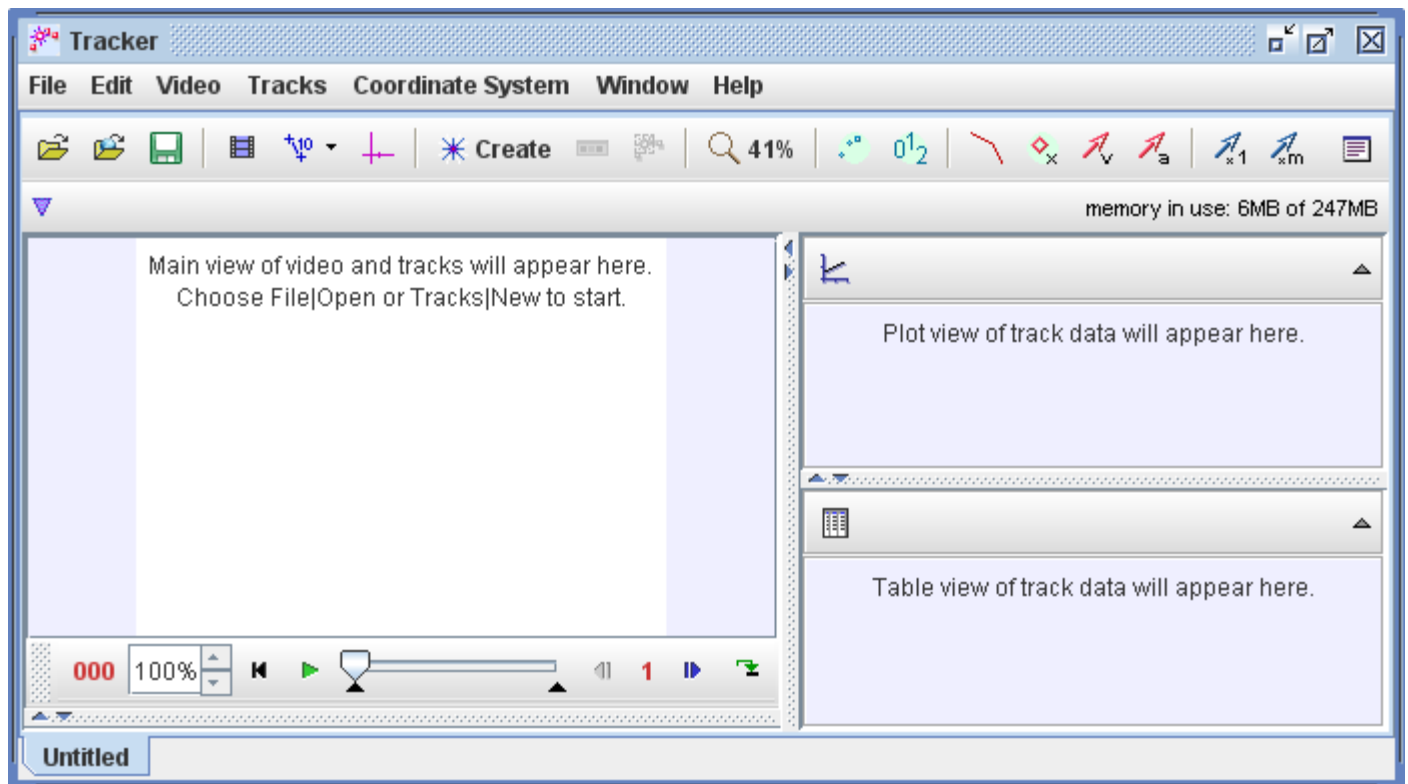
Tracker is a free video analysis and modeling tool built on the Open Source Physics (OSP) Java framework. Features include object tracking with position, velocity and acceleration overlays and graphs, special effect filters, multiple reference frames, calibration points, line profiles for analysis of spectra and interference patterns, and dynamic particle models. It is designed to be used in introductory college physics labs and lectures.

To start using Tracker, see [getting started](#).

Getting Started


When you first open Tracker it appears as shown below. Here's how to start analyzing a video:

1. [Open a video or tracker file.](#)
2. [Identify the frames \("video clip"\) you wish to analyze.](#)
3. [Calibrate the video scale.](#)
4. [Set the reference frame origin and angle.](#)
5. [Track objects of interest with the mouse.](#)
6. [Plot and analyze the tracks.](#)
7. [Save your work in a tracker file.](#)
8. [Export track data to a spreadsheet.](#)
9. [Print, save or copy/paste images for reports.](#)



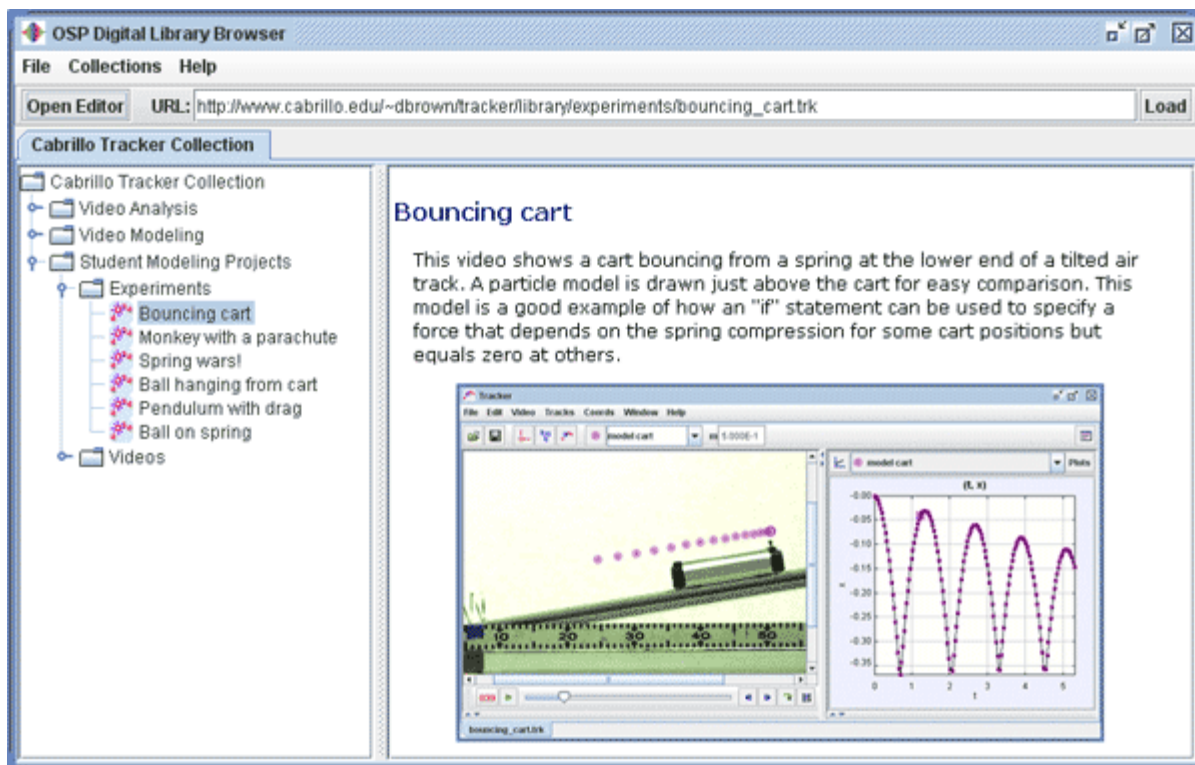
Note that the order of the buttons on the toolbar mirrors the steps used to analyze a video. For more information about Tracker's user interface, including user customization, see [user interface](#).

1. Open a video or tracker file

Click the Open button  or File|Open File menu item and select a digital video (mov, avi, mp4, flv, wmv, etc.), tracker data file (.trk), or zipped tracker file (.zip) to open. You can also open still and animated image files (.jpg, .gif, .png), numbered sequences of image files, and images pasted from the clipboard.

Play, scan or step through the video using the video player. For more information see [videos](#).

Another option is to open the OSP Digital Library Browser by clicking the Open Library Browser button or choosing the File|Open Library Browser menu item. The library browser enables you to browse and access collections of digital library resources including videos and tracker files. For help using the OSP Digital Library Browser, choose its Help|Library Browser Help menu item.

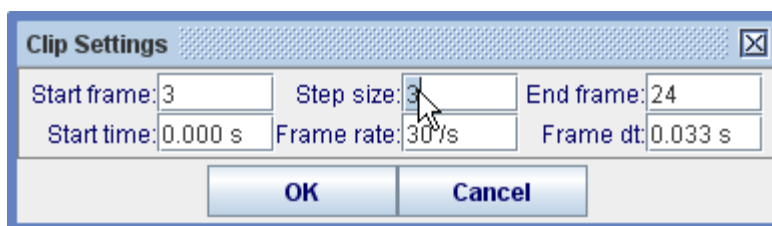


2. Identify the frames ("video clip") you wish to analyze

Display the clip settings by clicking the Clip Settings button  on the toolbar.

In the clip settings dialog, set the Start frame and End frame to define the range you wish to analyze. You can drag the player's slider to scan through the video and quickly find the frames of interest. If the video contains too many frames to analyze (more than 20 or so can become tedious), increase the Step size to automatically skip frames.

You can also set these video clip properties directly on the video player. For more information see [video clips](#).

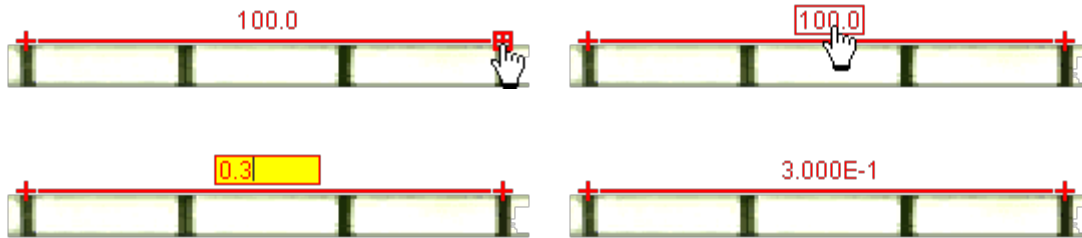


3. Calibrate the scale

Click the Calibration button  and select the [calibration stick](#).




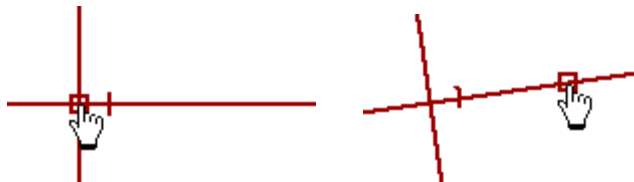
Drag the ends of the calibration stick to a video feature with known length (for example, a meter stick). Then click the readout to select it and enter the known length (without units). For example, in the figures below the scale is set in meter units using a video image of a white PVC pipe with black stripes every 10 cm.



For more information see [calibration stick](#), or for an alternate way to calibrate the video consider a [calibration point pair](#).


4. Set the reference frame origin and angle


Click the Axes button  to show the coordinate axes. Drag the origin and/or x-axis to set the reference frame origin and angle. A common choice for the origin is the initial position of an object of interest. For more information see [axes](#), or for alternate ways to set the origin and/or angle consider a [calibration point pair](#), an [offset origin](#) or the [calibration stick](#).



The scale and reference frame origin and angle uniquely define the coordinate system used to convert pixel image positions to scaled world coordinates. In some videos the coordinate system properties may vary from one frame to the next (e.g., if the camera is zoomed the scale will change, or if panned the origin will change). Tracker makes it relatively easy to handle such videos--see [coordinate system](#) for more information.

5. Track objects of interest with the mouse or model them with particle models.

Click the Create button  and choose a track type from the menu of choices. Most moving objects are tracked using a [Point Mass](#) track or modeled using a [Dynamic Particle Model](#) track.

 Create
Point Mass
Center Of Mass
Vector
Vector Sum
Line Profile
RGB Region
Analytic Particle Model
Dynamic Particle Model ▶
Measuring Tools ▶

When tracking an object, mark its position on every frame by holding down the shift key and clicking the mouse (crosshair cursor) as the video automatically steps through the video clip. Don't skip frames--if you do, velocities and accelerations cannot be determined.

Point mass tracks may also be marked automatically using [autotracker](#).

You can always adjust a marked position by dragging it with the mouse or selecting it and nudging with the arrow keys. Right-click the video to zoom in for sub-pixel accuracy.



If modeling an object, enter values and expressions into the Model Builder as shown below. The particle will automatically draw itself on the video when played.

Model Builder [X]

Model: projectile Start 0 End 9

Parameters

Add Copy Cut Paste

Name	Expression
m	1.0
g	9.8

Initial Values

Name	Expression
t	0.0
x	0.0
y	0.0
vx	3.0
wy	4.0

Force Functions

Add Copy Cut Paste

Name	Expression
fx	0.0
fy	-m*g

Double-click to edit a cell, or click Add to define a new parameter or function.

Help Undo Redo Font Size Close

You can change the name and appearance of a track by clicking its button on the track control and choosing from the popup menu. Other toolbar buttons let you show or hide paths, trails, labels, velocity vectors and acceleration vectors.

◇ mass A

Name...

Notes...

Color...

Footprint ▶

☒ Visible

☐ Locked

Define...

☒ Autostep

☐ Mark by Default

Velocity ▶

Acceleration ▶

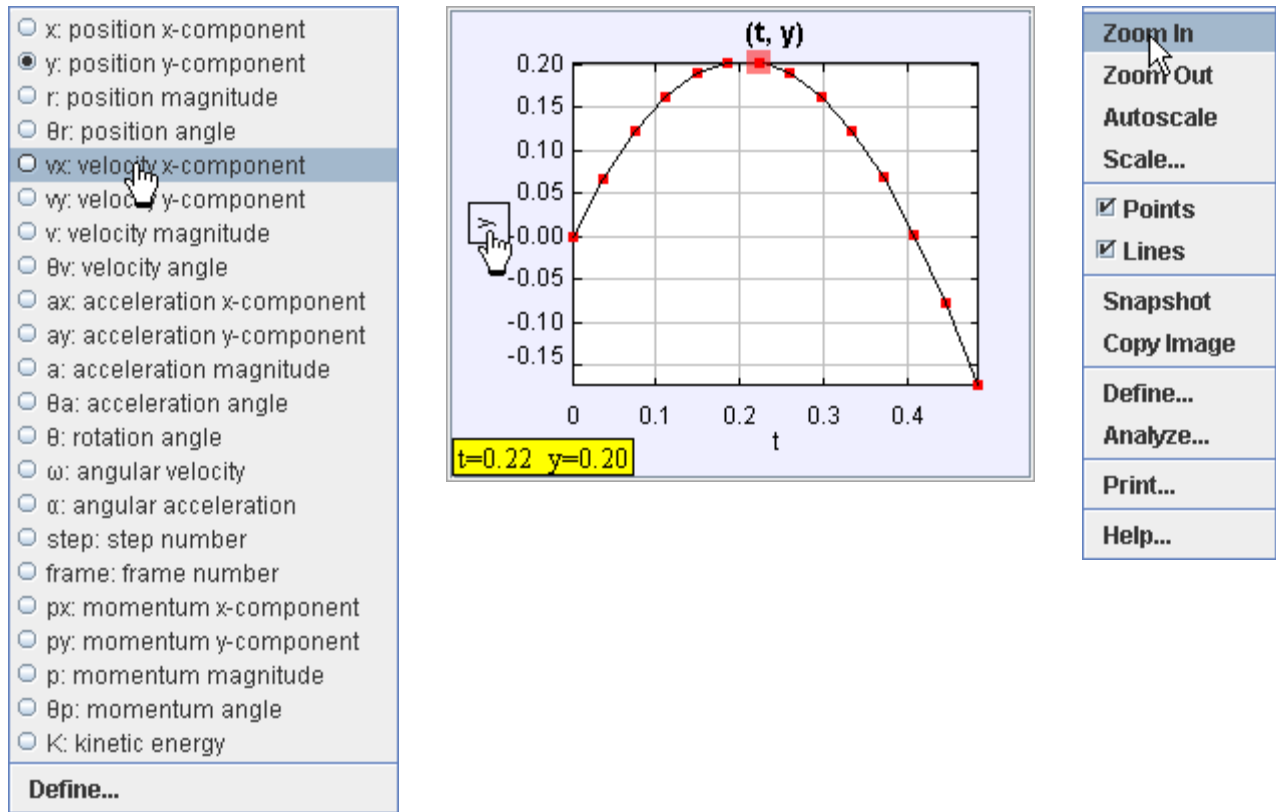
Clear Steps

Delete

For more information on tracks and the track control, see [tracks](#). For detailed information on a specific track type, see [point mass](#), [center of mass](#), [vector](#), [vector sum](#), [line profile](#), [rgb region](#), [particle model](#) or [two-body system](#).

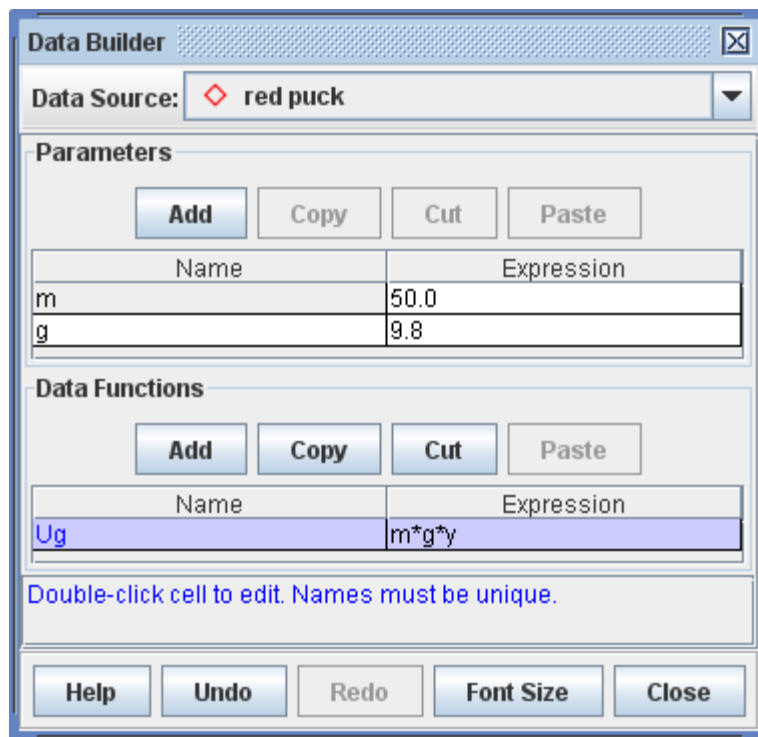
6. Plot and analyze the tracks

The Plot View displays graphs of track data. Click the x- or y-axis label to change the variable plotted on that axis. To plot multiple graphs, click the Plots button and select the desired number. Right-click on a plot to access display and analysis options in a popup menu.

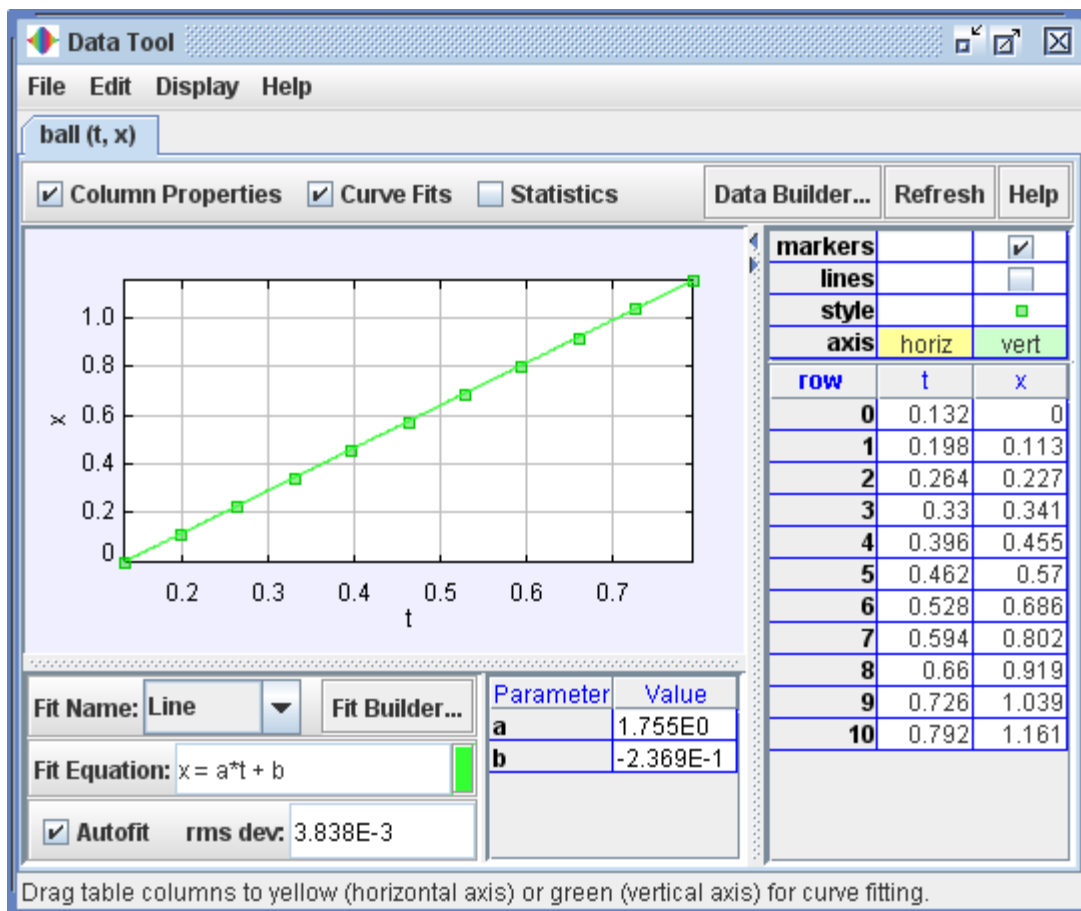


Two of the most powerful analysis options available from the popup menu are Define... and Analyze....


- The Define... item displays a Data Builder with which you can define custom variables for plots and datatables. Custom variables can be virtually any function of built-in and previously defined custom variables. For help using Data Builder, open Data Builder and click its Help button.



- The Analyze... item displays a Data Tool with statistics, curve-fitting and other analysis capabilities. For help using Data Tool, open Data Tool and click its Help button.



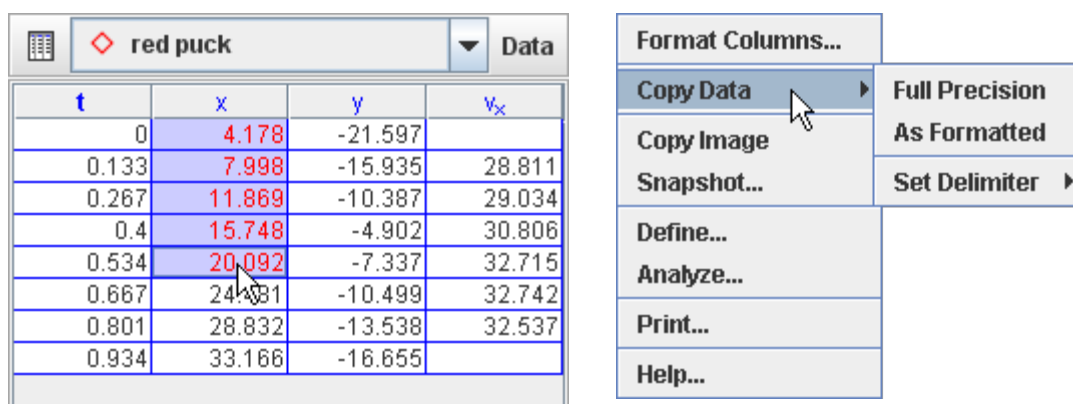
7. Save your work in a tracker (.trk) file

Click the Save button  or File|Save As... menu item to save your work in an XML-based tracker file with the extension ".trk". When a saved tracker file is opened, Tracker loads the video, sets the clip and coordinate system properties, and rebuilds all tracks, custom variables and views. For more information see [tracker files](#).

8. Export track data to a spreadsheet

Tracker's Datatable View displays track data in a table. To change the variables included in the table, click the Data button and select from the list displayed.

Data can be easily exported from the datatable by copying to the clipboard and pasting into a spreadsheet or other application. To copy, select the desired data in the table, then right-click and choose Copy Data from the popup menu. For more information see [datatable view](#).



The screenshot shows the Tracker interface with a 'red puck' track selected. The 'Data' button is clicked, opening a context menu. The 'Copy Data' option is highlighted, which has opened a sub-menu with options: 'Full Precision', 'As Formatted', and 'Set Delimiter'. The data table below shows the following values:

t	x	y	v _x
0	4.178	-21.597	
0.133	7.998	-15.935	28.811
0.267	11.869	-10.387	29.034
0.4	15.748	-4.902	30.806
0.534	20.092	-7.337	32.715
0.667	24.431	-10.499	32.742
0.801	28.832	-13.538	32.537
0.934	33.166	-16.655	

9. Print, save or copy/paste images for reports

You can print or copy an image of the entire Tracker frame or any individual view (e.g., a plot or datatable). To print the entire frame (all visible views), choose the File|Print... menu item. To print an individual view, right-click the view and choose Print... from the popup menu. To copy an image, choose the desired view from the Edit|Copy Image menu or right-click a view and choose Copy Image. Pasting printed or copied images into notes and reports is an excellent way to document your video analysis results.

To save an image, right-click on the view of interest and choose the Snapshot menu item. Then choose the File|Save Image menu item in the snapshot window.

Installation

Tracker requires Java but now supplies its own open-source video engine Xuggle. QuickTime is still supported but no longer required.

1. Verify and/or install Java

1. See if Java version 1.5 or higher (1.6 on Mac OS X) is installed on the host computer. If unsure, or Java is not installed, continue with the next step.
2. Download the most recent Java installer from <http://java.sun.com/javase/downloads/>. The JRE (Java Runtime Environment) is all you need unless you're a Java developer.
3. Double-click the installer and follow the instructions.

2. Install Tracker (with Xuggle)

1. Download the tracker installer for your platform (Windows, Mac OS X, or Linux) from Tracker's home page at <http://www.cabrillo.edu/~dbrown/tracker/>.
2. Follow the Installer Help instructions at http://www.cabrillo.edu/~dbrown/tracker/installers/installer_help.html. Be sure to include Xuggle in the installation for maximum functionality.

3. Upgrade Tracker

1. Download the tracker installer for your platform, choose the Upgrade option and follow the instructions. Upgrades may include Tracker, Xuggle and/or other components.

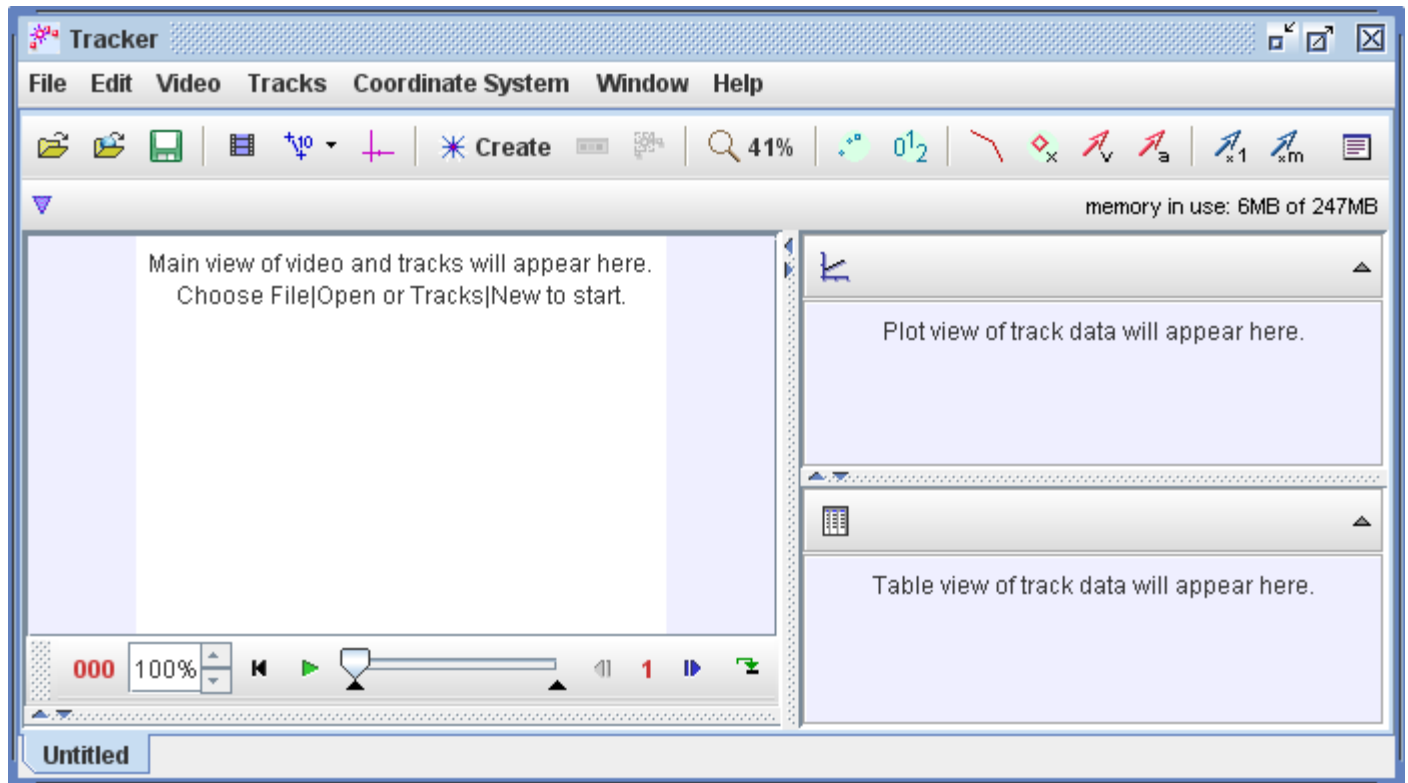
4. Launch Tracker

1. Windows: choose the Tracker item in the Start Menu.
2. OS X: double-click the Applications/Tracker.app file.
3. Linux: select the Applications|Education|Tracker menu item.


Congratulations! To start using Tracker, see [getting started](#).

User Interface

1. Main view



Each Tracker tab, like "Untitled" above, displays the following components:

- A main video view that displays video images with track overlays. The video view has a fixed, stable video image. Tracks are marked and edited in the video view.
- A menu bar that offers access to most program commands and settings. Some menu items include icons showing which toolbar buttons perform identical actions.
- A two-tiered [toolbar](#), displayed directly below the menu bar, that offers quick access to frequently used controls, tools, track settings and data fields.
- A [player](#) that controls the video playback and video clip settings.
- [Additional views](#) in attached view panes. Open, close or resize a view by clicking or dragging the thin dividers between panes or by selecting the desired view from the Window menu. Maximize or restore a view by clicking its Maximize button  or double-clicking its toolbar.

2. Toolbar

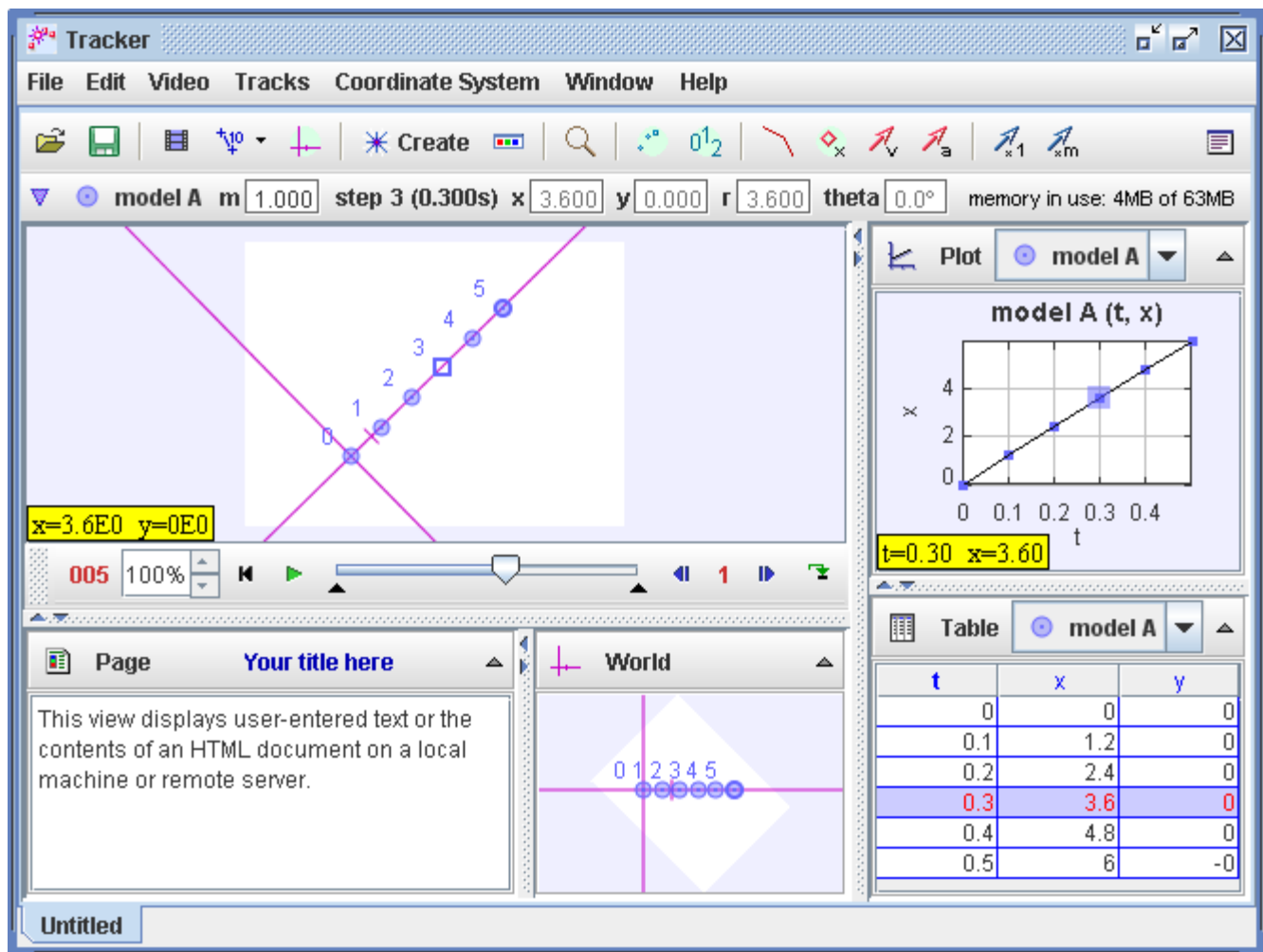


The order of the buttons on the main toolbar closely match the steps used to analyze a video. They include (from left to right):

- Open button opens a digital video or tracker file in a new tab.
- Open Library Browser button opens the OSP Digital Library Browser for web-based videos and tracker files.
- Save button saves the current tab in a [tracker file](#).
- Clip Settings button shows and hides the [clip inspector](#).
- Calibration button shows and hides the [calibration stick](#), [calibration points](#) and/or [offset origin](#).
- Axes button shows and hides the [coordinate axes](#).
- Create button creates a new [track](#) in the current tab.
- Track Control button shows and hides the [track control](#).
- Zoom button turns on the [zoom tool](#).
- Trails button sets the length of all trails.
- Labels button shows and hides all labels.
- Path button shows and hides all paths.
- Positions button shows and hides all point mass positions.
- Velocities button shows and hides all point mass velocity vectors.
- Accelerations button shows and hides all point mass acceleration vectors.
- Stretch button stretches all vectors.
- Dynamics button multiplies all motion vectors by mass.
- Notes button shows and hides the [notes window](#).

The lower tier of the toolbar is used mainly for selected track data and input fields, but also contains a memory manager button that manages and monitors Tracker's memory status. See [memory management](#) for more information.

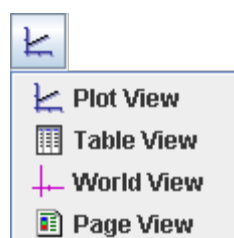
3. Additional views



Here a particle model track has been added and the split panes have been opened to display all view types and positions.

- The main video view (pane 0--top left) displays the video and tracks in video space. In this example, the video view keeps the video image (white background) fixed even though the axes are tilted.
- The plot view (pane 1--top right) displays one or more graphs of track-generated data. Multiple graphs are stacked vertically.
- The table view (pane 2--bottom right) displays a data table of track-generated data.
- The world view (pane 3--bottom center) displays the video and tracks in world space. The world view keeps the axes fixed (with the x-axis pointing right), so the video is tilted.
- The page view (pane 4--bottom left) displays text and html pages.

Except for the main video view, any view pane can display any type of view. To select a desired view type, click the view chooser button at the left end of a view toolbar and choose from the drop-down list.



4. Hints

By default, Tracker displays hints in a yellow box at the bottom right corner of the main view. Hints are very useful for new and occasional users of Tracker. Experienced users can turn off hints by unchecking the Show Hints checkbox in the Help menu or in the Display tab of the [preferences dialog](#).



5. Background mat

The background mat is a white area normally hidden behind the video. It is never smaller than the video, but may be made larger if desired by choosing from the Edit|Mat Size menu. A larger mat size increases the area that is drawn in the video and world views. This is useful when some of a track's steps, or the axes, would otherwise be drawn offscreen--a common situation when using [particle model](#) tracks, [calibration point pairs](#) or [offset origins](#).

6. Languages

Select a language other than that of the default locale by choosing from the Edit|Language menu or in the Display tab of the [preferences dialog](#).

If your preferred language is not available, and you wish to provide a translation, please contact Douglas Brown at dobrown@cabrillo.edu.

7. Undo and redo

Most operations in Tracker can be undone and redone using the Undo and Redo items in the Edit menu. There is no limit to the number of undo actions.

8. Memory management

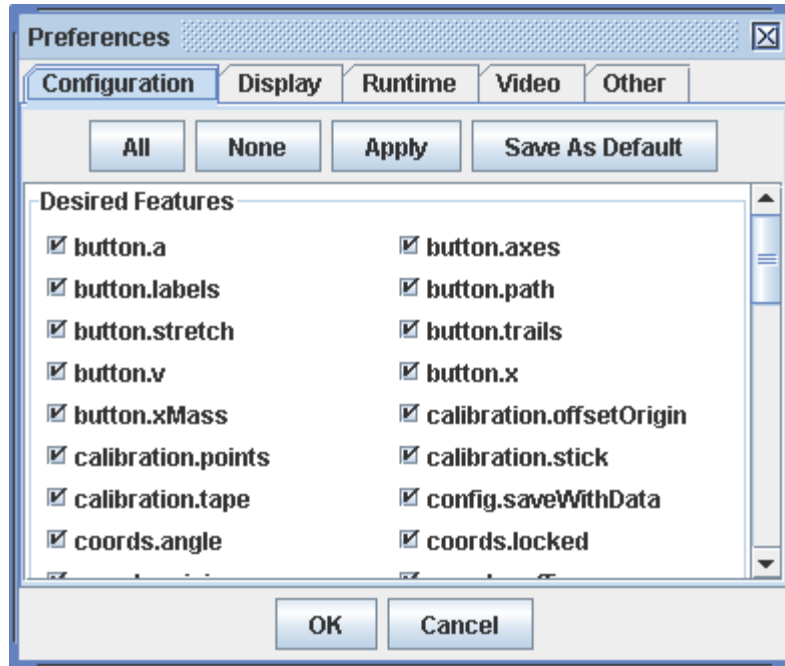
By default Tracker has at least 64MB of memory available (machine-dependent), enough to handle most moderate-sized videos. But when analyzing large or multiple videos, or long image sequences, additional memory will likely be needed. The memory manager button on the lower tier of the [toolbar](#) displays information about the current memory status. The button text turns red when the current memory limit is approached.

Larger memory sizes are set in the Runtime tab of the [preferences dialog](#). Clicking the memory manager button pops up a menu item that provides easy access to this tab.



9. Tracker Preferences

The preferences dialog enables a user to set a preferred configuration, memory size and other properties of Tracker. These preferences are saved in a ".tracker.prefs" file that is automatically read every time Tracker starts. To display the preferences dialog, choose the Edit|Preferences menu item.



Set preferences in the following tabs:

1. Configuration tab. The "configuration" refers to the menus, buttons and other user interface features included in Tracker. By unchecking items in the configuration tab, you can hide unwanted features. This is particularly useful when introducing students to Tracker for the first time. As they gain familiarity with the program, additional features can be displayed as needed.

When the `config.saveWithData` item is checked, a customized configuration will be included in the tracker data file (.trk) when a Tracker tab is saved. A configuration saved in a trk file will override the default configuration when the tab is loaded.

To set a configuration as the default (ie, for new tabs and tabs loaded from trk files without a custom configuration), click the Save As Default button.

2. Display tab. Select a preferred language from the dropdown list. Check the Show hints by default checkbox to show hints on startup. Select degrees or radians for the default angle units.
3. Runtime tab. Set a preferred memory size or check the Use default checkbox to accept the default size (commonly 64MB, but may vary). Select a preferred look and feel from the dropdown list or choose default to accept the default look and feel (varies with platform).

To relaunch Tracker immediately with a new memory size or look and feel, click the Relaunch Now button.

4. Video tab. Select a preferred video engine (Xuggle or QuickTime) if both are available on your machine. Select the fast (may be jerky) or smooth (may be slow) playback option for videos opened with Xuggle.
5. Other tab. Set the preferred number of files displayed in the File|Open Recent menu, or clear the current menu items. Set a preferred cache directory for downloaded web files, or click the Clear button to clear the cache. Select a preferred interval to automatically check for upgrades or click the Check Now button to check immediately.

Videos

Tracker can analyze three different video types:

1. digital video files (.mov, .avi, .mp4, .flv, .wmv, etc.) which require a video engine (see below).
2. animated GIF files (.gif).
3. image sequences consisting of one or more digital images (.jpg, .png or pasted from the clipboard).

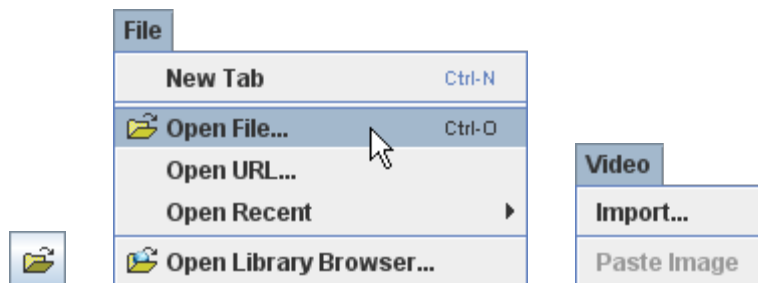
In addition, two different video engines are now supported:

1. Xuggle (Windows, Mac, Linux) opens most digital video files including .mov, .avi and .mp4.
2. QuickTime (Windows, Mac) opens .mov, .avi and .mp4 files only.

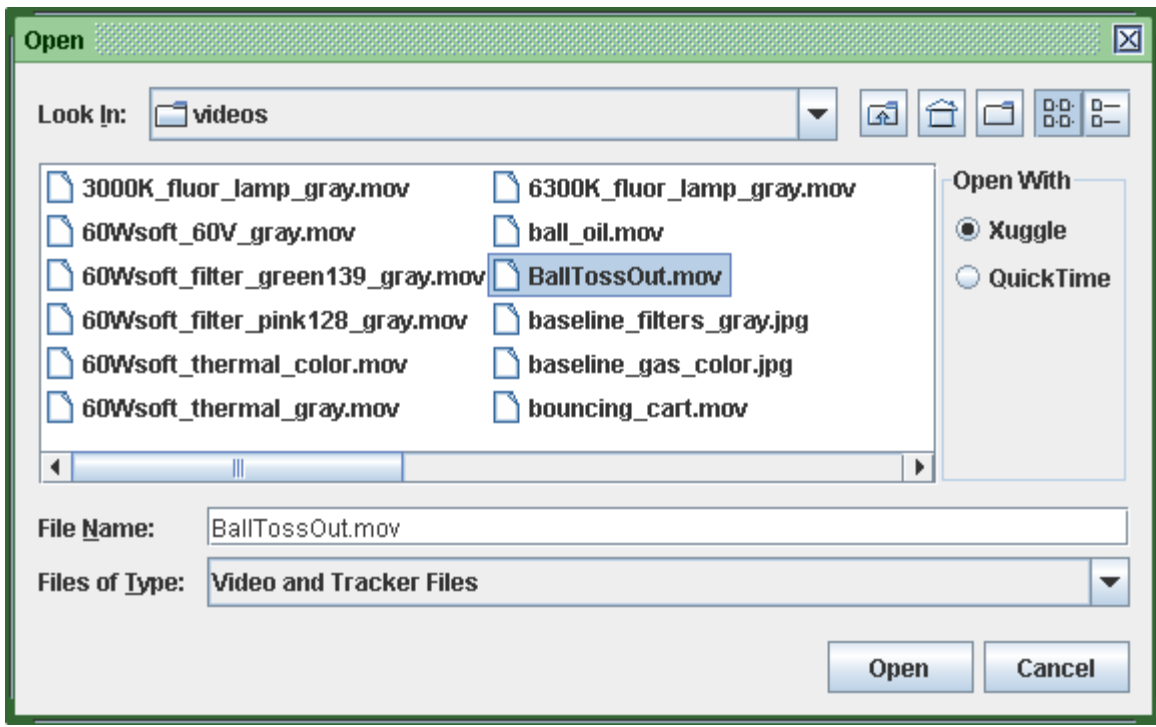
If both Xuggle and QuickTime are installed you can specify a preferred video engine in the Video tab of the [preferences dialog](#). Xuggle is preferred by default.

1. Opening or importing a video from a local drive

To open a video into a new tab, use the Open button or File|Open File menu item. To import a video into an existing tab, use the Video|Import, Video|Replace or File|Import|Video menu item.

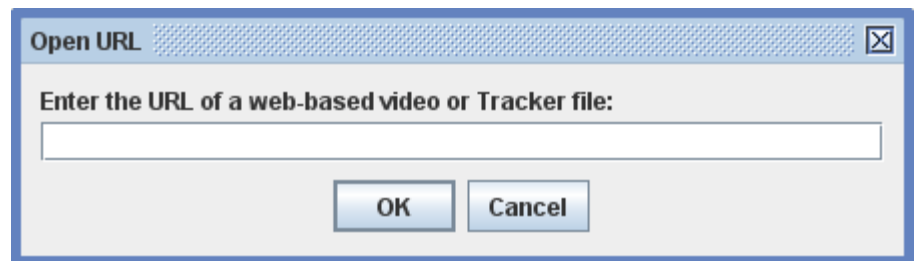


Select the desired video in the file chooser to open it. If the file can be opened with both Xuggle and QuickTime you will be given a choice as shown.

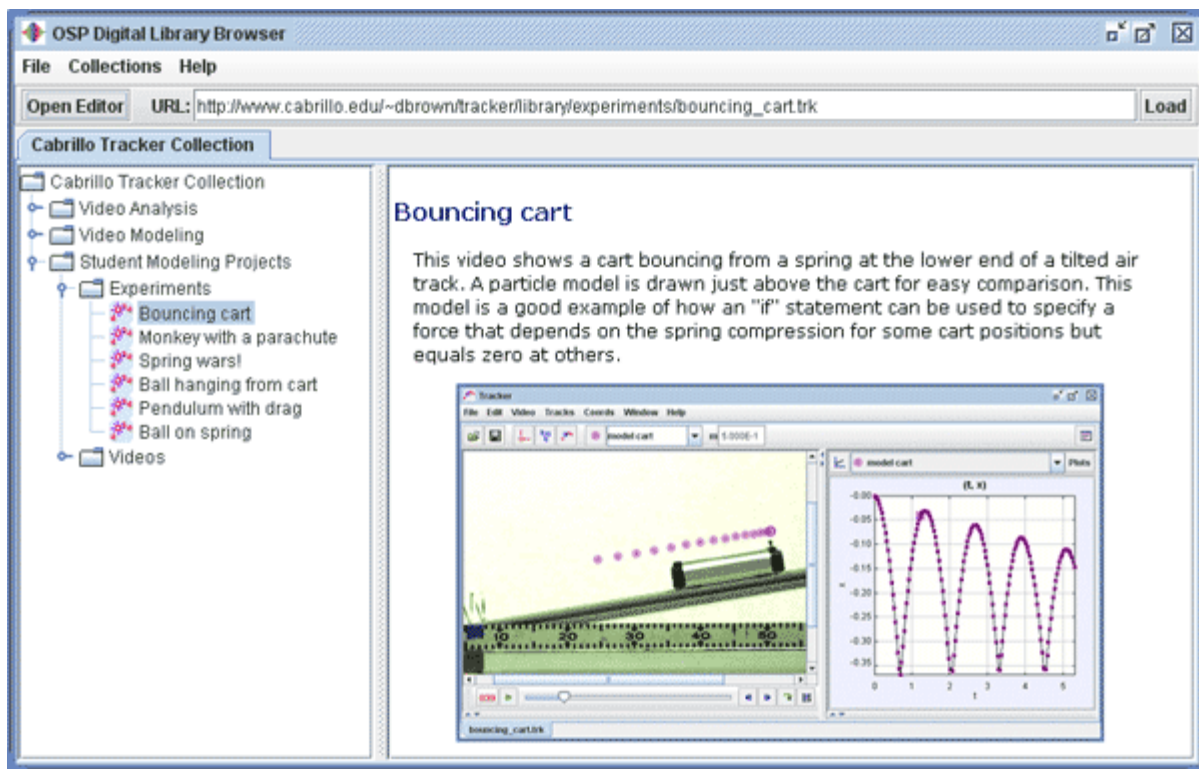


2. Opening a video from the web

Choose the File|Open URL menu item and enter a known URL in the dialog to open a video directly from the web.



Another option is the OSP Digital Library Browser. Open the browser by clicking the Open Library Browser button or choosing the File|Open Library Browser menu item. The library browser enables you to browse and access collections of digital library resources including videos and tracker files. For help using the OSP Digital Library Browser, choose its Help|Library Browser Help menu item.



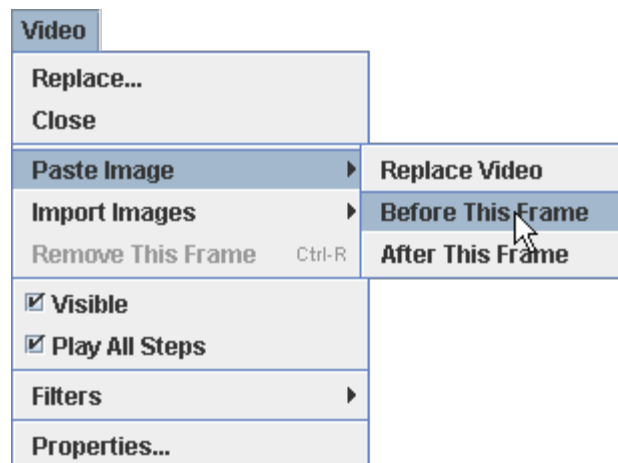
3. Opening numbered image sequences

Tracker will automatically open a sequence of up to 1000 JPG or PNG images that are numbered sequentially. To open a sequence, select only the first image in the sequence.

Image sequence numbering must have a fixed format. For example, selecting the first image in a sequence numbered image00.jpg to image14.jpg will open all 15 images, but if the sequence is numbered image0.jpg to image14.jpg then only the first 10 images will be opened (i.e., up to image9.jpg).

4. Pasting images from the clipboard

Images that have been copied to the clipboard may be pasted directly into Tracker for analysis. Choose the Video|Paste Image or Video|Paste Image|Replace Video menu item to create a new image video.

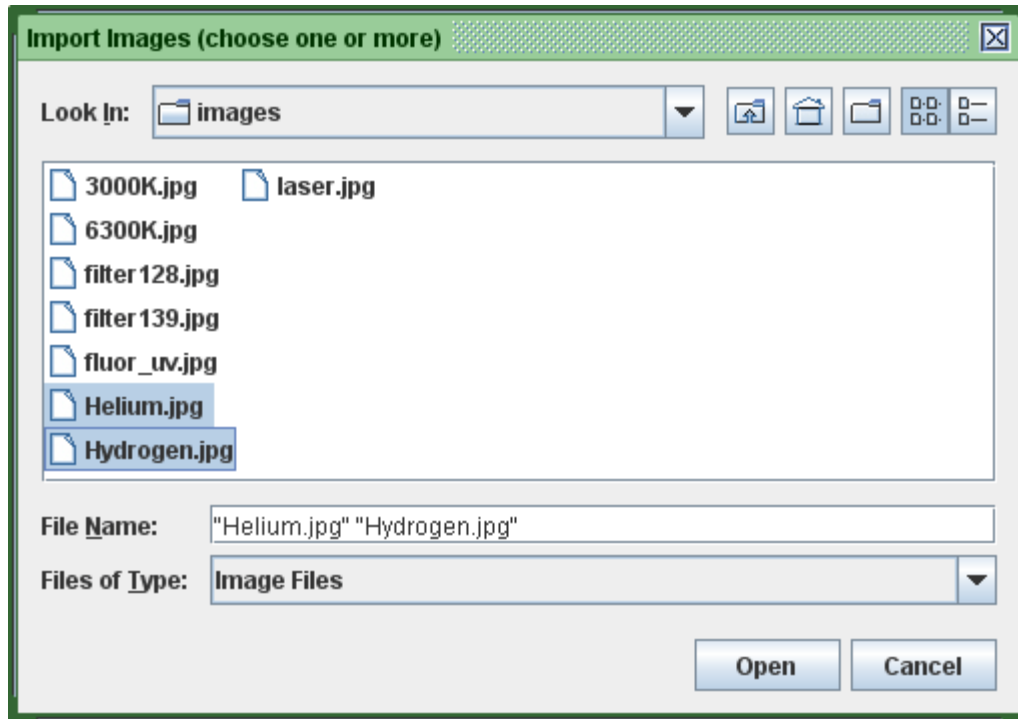


5. Adding and removing images from an image video

Once an image video has been created, you can paste or import additional images using the Video|Paste Image or Video|Import Images menu choices Before This Frame or After This Frame.

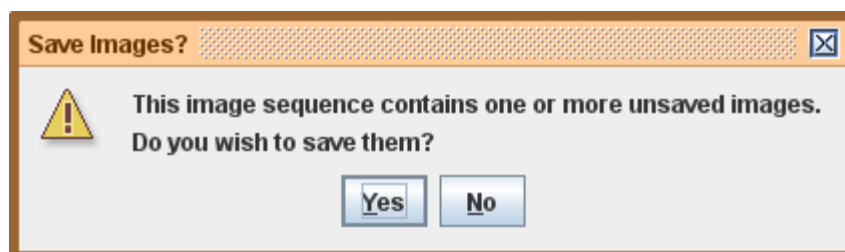
To remove images from an image video use the Video|Remove This Frame item.

When importing images you can select multiple images in the file chooser by control-clicking or shift-clicking.



6. Saving pasted images

When closing or saving an image video that contains pasted images, a warning dialog prompts you to save the images as files if desired. You must save the images if you wish to reopen them at a later time.



7. Video clips

A video clip is a subset of frames in a video defined by:

1. start frame
2. step size (number of frames per step)
3. end frame

The start frame is the frame number of the first step, the step size is the frame increment between successive steps, and the end frame is the frame number of the last step. For example, a clip with start frame

3, step size 2 and end frame 11 would consist of step numbers 0, 1, 2, 3 and 4 that map to video frame numbers 3, 5, 7, 9 and 11, respectively. (Note: the end frame must be an integer number of steps downstream from the start frame.)

A clip is defined for every video and even for null videos. For single-frame and null videos the clip settings apply to tracks but every step maps to the same video image.

Video clip properties are set with the [video player](#) and/or the [clip inspector](#).

Note:

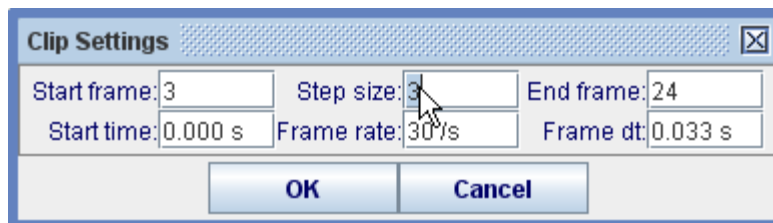
- Clip properties should be set and/or reviewed *before* creating and marking tracks.
- Tracks should be marked on all frames in the clip so that v and a can be determined.
- Changing the step size after marking can result in gaps in the data until missing frames are marked.

8. Clip inspector

To display the clip inspector, click the Clip Settings button on the toolbar.

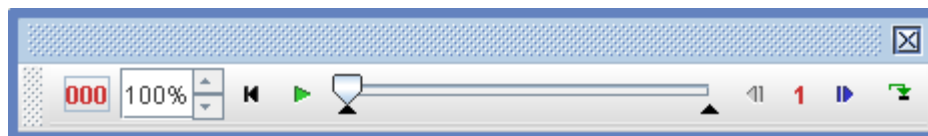


The clip inspector shows the current video clip settings and also provides fields for setting a start time (time assigned to step 0), the true frame rate (important for high-speed or time-lapse videos) and the time interval dt between frames (inverse of the frame rate).



9. Using the video player

The video player is normally attached to the video view, but you can drag the entire player by the left end to convert it to a floating window if desired.



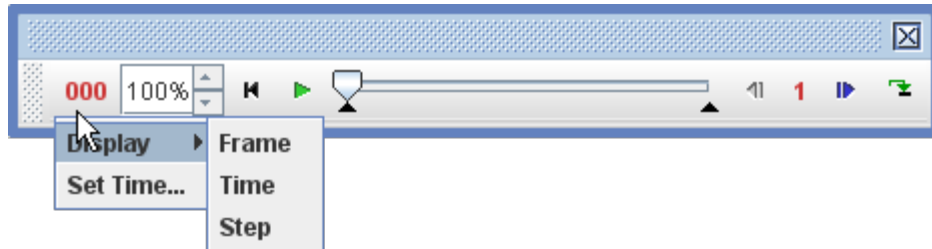
The player includes (from left to right):

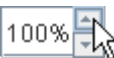
- time/step/frame readout
- play rate field and control
- reset button
- play/pause button
- scan slider with start and end frame controls

back button


- step size control
- step button
- loop button

Click the readout to display frame number (measured from the beginning of the video), time in seconds (measured from the start time) or step number (measured from the start frame). The readout displays frame number by default.

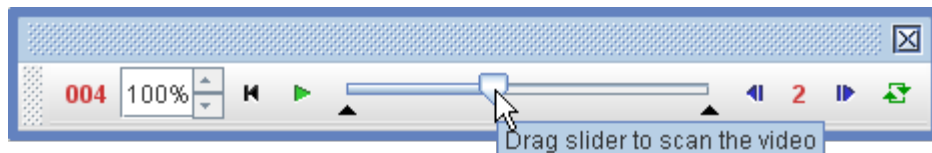


Use the rate spinner  to set the play rate (% of normal) or enter a desired rate directly in the field.

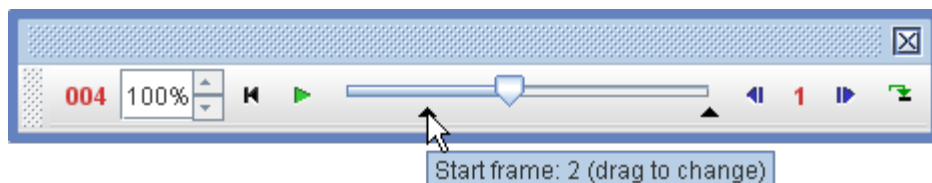
Click the reset button  to reset the video to step 0.



Click the play/pause button  to play the video; click again to pause.

Drag the slider to scan a video or move quickly to a desired frame.

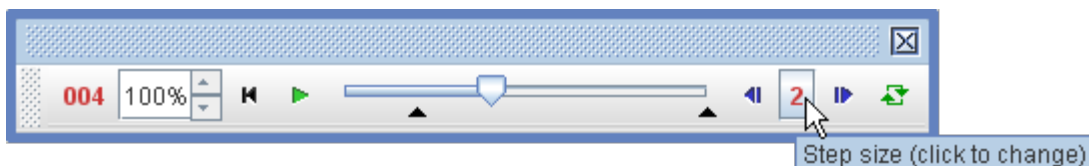



Drag the black in- and out-point markers, or right-click the slider, to set the start and end frames.



Click the step button  to step forward one step, or use the keyboard shortcut PageDown. Click the back button  to step back one step, or use the keyboard shortcut PageUp.


Click the step size control to set the step size in frames per step.

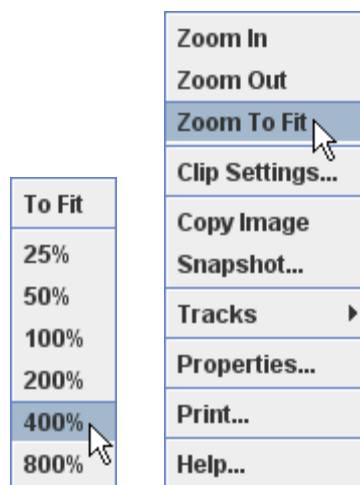


Click the loop button  to toggle looping (continuous play).

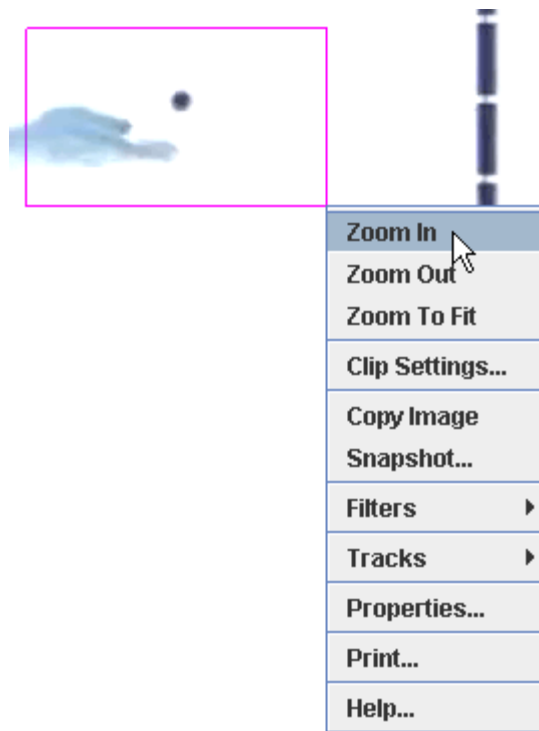
10. Magnifying (zooming) a video

There are four ways to change the magnification of the video for more accurate marking:

1. Click the zoom button on the toolbar  and choose the desired zoom level from the dropdown menu as shown in below. Tip: Double-click the zoom button to set the zoom level To Fit so the video image fits exactly in the main video view.
2. Position the cursor over a region of interest and roll the mouse wheel forward to zoom in, back to zoom out.
3. Right-click on a region of interest and choose Zoom In, Zoom Out or Zoom To Fit from the popup menu.
4. Drag a zoom box using the right button and choose Zoom In to zoom to the box as shown below.
5. Press the Z key (mouse cursor displays a zoom icon) and click or drag the mouse to zoom in. Hold down the Alt key at the same time to zoom out.



Zoom button dropdown (left) and right-click popup (right) menus



Right-drag and zoom to the box

11. Video filters

Video filters allow you to modify the video image. See [video filters](#) for complete filter descriptions.

12. Hiding and closing a video

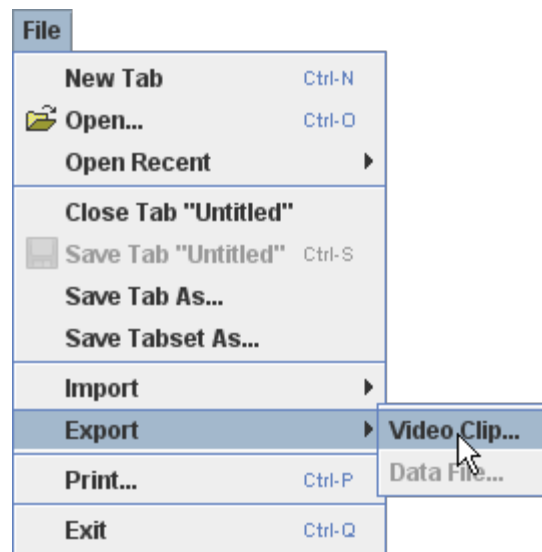
Uncheck the Video|Visible menu item to hide the video image and display the tracks on a white background. Choose Video|Close to remove the video permanently.

Note: when removing or replacing a video, a new video clip is created. This may result in some tracks having existing steps that are no longer included in the clip or unmarked steps that are newly included. If this happens, correct the problem by resetting the start frame, step size and end frame for the new clip.

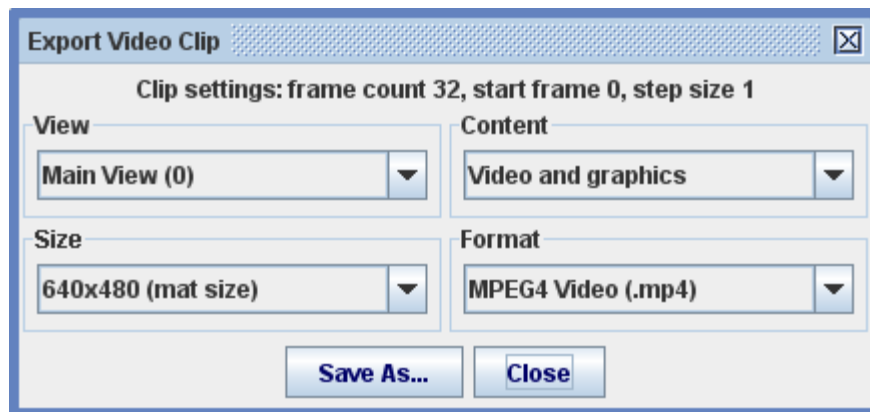
13. Exporting a video clip

Tracker can export the current video clip as a digital video file, animated GIF or image sequence, thus serving as a simple video editor and transcoder. But exported videos can also include track overlays, video filters, and additional views like world views and plots, making them useful for documenting the video modeling or analysis results.

Note: the exported video contains only frames in the current video clip (determined by start frame, step size and end frame), not the entire video.

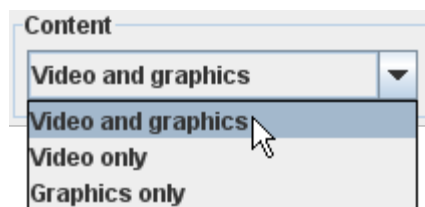


To export a video clip, select the File|Export|Video Clip... menu. This will bring up the Export Video Clip dialog.



Select the view, content, size and format of the exported video from the dropdown lists. The content choices depend on the selected view as follows:

1. Main view: Video and graphics, Video only or Graphics only
2. World view: Video and graphics or Graphics only
3. Other views: Graphics only



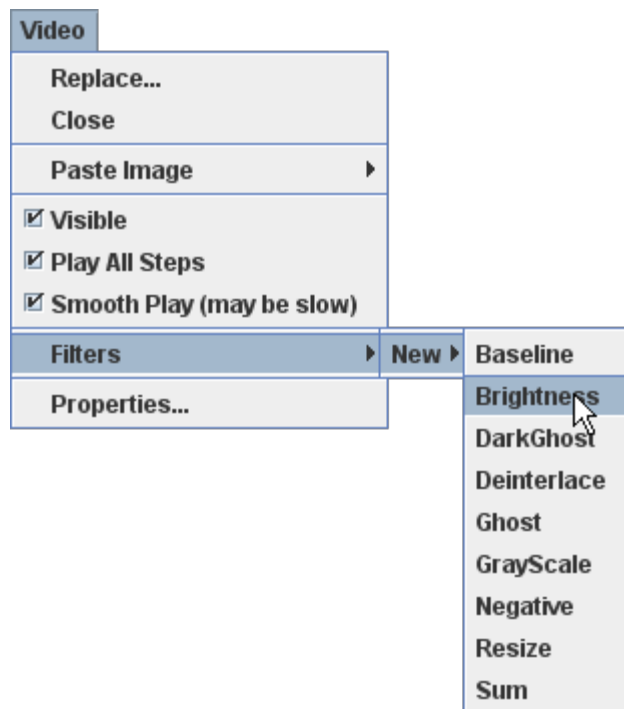
Video Filters

Video filters allow you to modify the video image for special effects or to improve the quality of data obtained from tracks. Tracker's filters fall into four general categories:

1. Image enhancement: [brightness/contrast](#), [deinterlace](#)
2. Special effects: [ghost](#), [dark ghost](#), [greyscale](#), [negative](#)
3. Noise reduction: [baseline](#), [sum/average](#)
4. Image transformations: [perspective](#), [resize](#), [rotate](#)

1. Applying filters to a video

Create a new filter with the Video|Filters|New menu. Multiple filters are applied in the order in which they are created and listed in the Video|Filters menu. Existing filters can be temporarily disabled or permanently deleted. Choose Video|Filters|Clear to delete all filters.



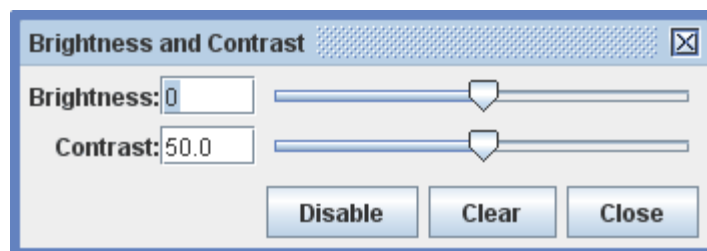
2. Setting a filter's properties

Most filters have a properties dialog that enables the user to set filter parameters. The dialog pops up when the filter is created and remains accessible from the Video/Filters menu. Every dialog has a Disable button that temporarily disables the filter so it has no effect.



3. Brightness/contrast filter

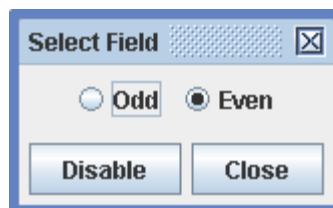
The brightness filter has adjustments for both brightness (range -128 to +128) and contrast (range 0-100). Changes in brightness affect the RGB components of all pixels equally until minimum (0) or maximum (255) values are reached.



To set a value, use the slider or enter it directly in a field. The Clear button resets the brightness and contrast to their default values.

4. Deinterlace filter

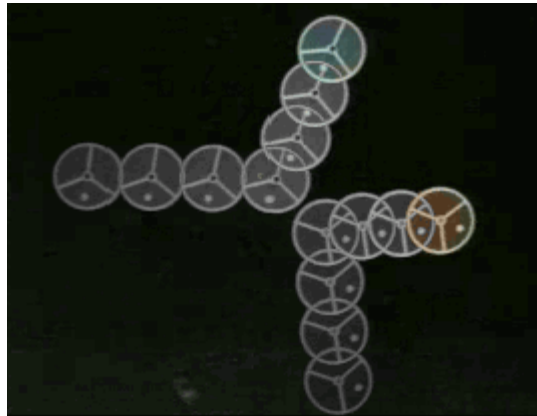
The deinterlace filter is used to eliminate double images that appear in interlaced videos.



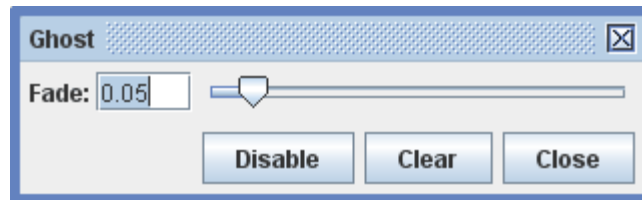
Each frame of a 30 fps interlaced video consists of two fields, odd and even, that are captured 1/60 s apart. Each field contains a complete image with half the vertical resolution of the frame. When played on an interlaced TV the fields are displayed sequentially so the separate images result in smoother motion, but when viewed one frame at a time in Tracker the fields are combined, resulting in a double image. The interlace filter corrects the problem by displaying only one of the fields. Note that this also reduces the vertical resolution.

5. Ghost filter

The ghost filter leaves a trail of fading ghost images of a moving bright object against a dark background. The effect is produced only when the video is played or stepped. The "live" motion diagram that results can be a very effective tool for learning the concepts of position, velocity and acceleration.



To set the rate at which the ghosts fade, use the slider or enter a value directly in the field. The Clear button clears all current ghosts from the image.



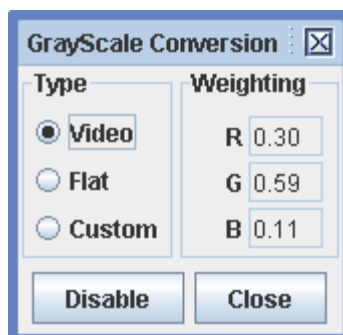
6. Dark ghost filter

The dark ghost filter is like the ghost filter above except that it works with moving dark object against a bright background.

7. Grayscale filter

The grayscale filter converts a color image into a grayscale image. This is useful for extracting brightness data (gray level 0-255) from RGB components. The conversion uses separate RGB weighting factors in the equation:

$$\text{gray level} = (R \cdot \text{weightR} + G \cdot \text{weightG} + B \cdot \text{weightB}) / (\text{weightR} + \text{weightG} + \text{weightB})$$



The filter includes standard weighting factors for video and flat-response images but also allows advanced

users to define custom weighting factors.

8. Negative filter

The negative filter produces a negative image in which each pixel RGB component x becomes $255-x$. This is often useful when printing, particularly when combined with a brightness filter, since dark features against a light background are often clearer (and use less ink!) than light features against a dark background.

There is no properties dialog for the negative filter since there is nothing to adjust.

9. Baseline filter

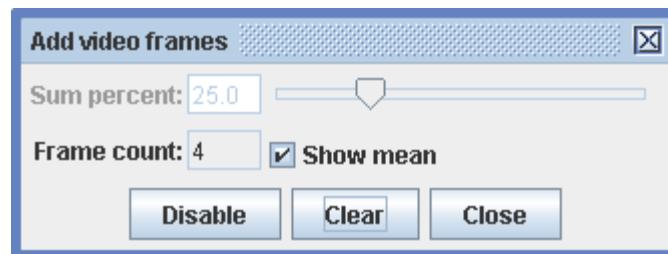
The baseline filter subtracts a "baseline" image from the video images. If the baseline is the (unchanging) background in the video scene, the background is eliminated, leaving black. This is particularly useful when using a [line profile](#) or [rgb region](#) to measure RGB values in spectral or other images contaminated with unwanted background light--simply capture an image or video of the background light alone (i.e., with the spectral light source turned off) and use it as the baseline.



To set a baseline image, use the Load button to load the image from a file or the Capture button to capture the video image currently displayed in Tracker. The Clear button removes the current baseline image.

10. Sum/average filter

The sum filter adds video images together (separate RGB components) and displays a fraction of the result. When the Show mean checkbox is selected, the fraction is automatically adjusted to display the mean RGB values of the images. This can significantly reduce the RGB noise in videos of spectra or other optical phenomena.



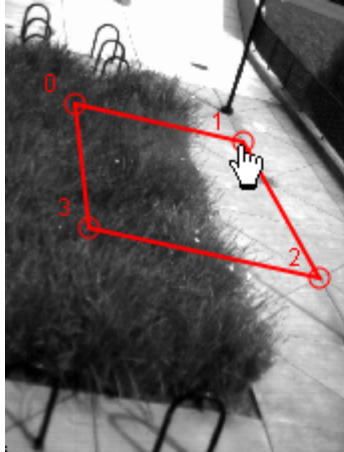
When the Show mean checkbox is not selected, use the slider or enter a percent directly in the field. The Clear button resets the sum to the current image.

11. Perspective filter

The perspective filter can correct the distortion that occurs when an object is photographed from an angle rather than straight-on. It does so by mapping a distorted plane shape in the input image to a straight-on

plane shape (rectangle by default) in the output image. The input and output shapes are adjusted by dragging their corners. To use the filter:

1. Select the Input tab and define the distorted plane in the input image.
2. Select the Output tab and define the straight-on plane in the output image. Adjust the output plane dimensions so that the horizontal and vertical scales are equal (this may be unnecessary for 1D motion).



Perspective Filter [X]

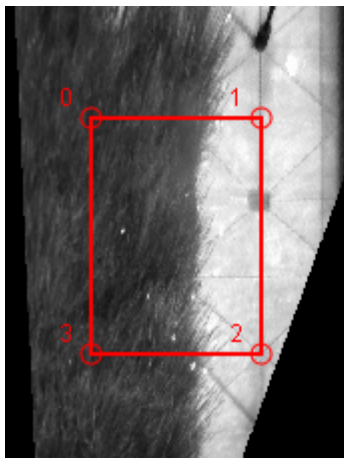
Input **Output**

Shape: Any

Corner Positions in Pixels

0: x 99.0 y 148.0	1: x 336.0 y 201.0
3: x 117.0 y 322.0	2: x 444.0 y 394.0

Help Color Disable Close



Perspective Filter [X]

Input **Output**

Shape: Rectangle

Corner Positions in Pixels

0: x 120.0 y 160.0	1: x 361.0 y 160.0
3: x 120.0 y 492.0	2: x 361.0 y 492.0

Help Color Disable Close

12. Resize filter

The resize filter changes the dimensions of the video image. This is particularly useful for correcting the distortions that result when the non-square pixels in DV-formatted videos are displayed and analyzed in Tracker's square pixel environment. This causes the image to be stretched horizontally. The stretch can be corrected by resizing the image from 720x480 to 640x480 as shown.

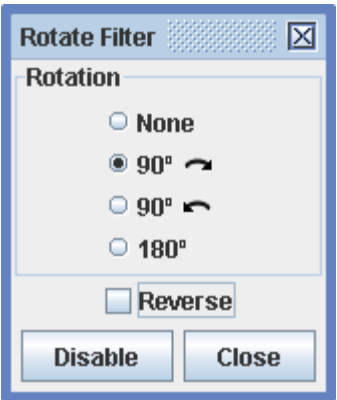
Resize Filter [X]

	Width	Height
Input	720	480
Output	640	480

Disable Close

13. Rotate filter

The rotate filter rotates in 90 degree increments and/or reverses the video image. Rotation is useful for videos shot in portrait rather than landscape orientation. Reversing the image flips right and left before rotating.



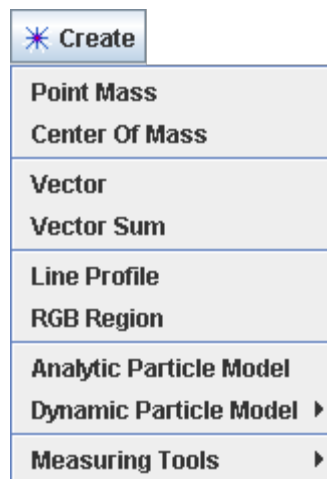
Tracks

A track represents a video feature that evolves over time. All interactive elements in Tracker, including the axes, measuring tools and calibration tools, are tracks.

The position or shape of the feature in a single video frame is known as a step; thus, a track is a series of steps. Each step can be selected and manipulated with the mouse or keyboard. Some steps, like those for point mass tracks, have only a single moveable point, but others, like vector steps, have two end points plus a center handle point.

There are several types of user-defined tracks and two measuring tools. For detailed information on a specific type, see its corresponding help topic: [point mass](#), [center of mass](#), [vector](#), [vector sum](#), [line profile](#), [rgb region](#), [analytic particle model](#), [dynamic particle model](#) (cartesian, polar or [two-body system](#)), [tape measure](#) and [protractor](#).

1. Creating a track



Create a new track by selecting the desired track type from the Create button menu on the toolbar or the Track|New menu on the menu bar. A newly created track is automatically selected for marking.

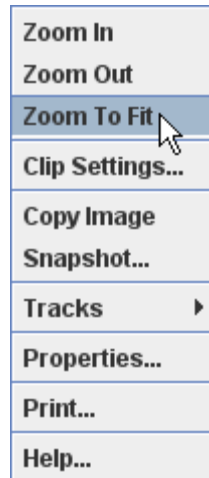
2. Marking a track



Marking a track refers to the process of defining its position on each frame in the video clip. Point mass tracks are special in that they can be marked either manually or automatically using [autotracker](#). All other tracks must be marked manually using the crosshair cursor (shown above at twice actual size). To mark manually, hold down the shift key and click the mouse on the feature of interest as the video automatically steps through the video clip. Don't skip frames--if you do, velocities and accelerations cannot be determined.

When marking point mass and vector tracks, you can hit the enter key instead of clicking the mouse to mark a step at the exact location of the previous step. This can be useful when marking an object at rest.

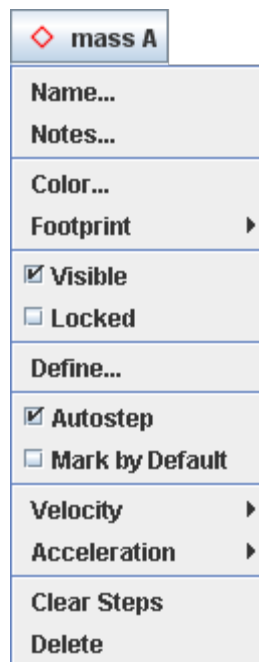
Marking is done in the main video view. For more accurate marking, magnify the image up to 8x using the [zoom tool](#) or by right-clicking on the video and choosing the desired zoom level.



There is some variability in marking requirements for the various track types. Vector and line profile tracks require dragging rather than clicking. Point mass and vector tracks expect every step to be marked, but offset origin, calibration point pair, line profile and rgb region tracks require marking only a single frame. Center of mass, vector sum, particle model and two-body system tracks are marked automatically.

In rare circumstances you may wish to control the marking process in more detail. If you prefer that the video not automatically step forward while marking you can uncheck the Autostep option.

3. Track buttons and menus



Every track has a track button that shows its name, color and footprint, and a track menu with items for setting its properties. Track buttons are displayed on both the [toolbar](#) and the [track control](#). Track menus can be accessed by (a) clicking the track button, (b) choosing the track from the Tracks menu on the menu bar, or (c) right-clicking the main video view and choosing the track from the Tracks popup menu.

4. Track control



The track control displays a track button for each user-created track. This makes it easy to select tracks and provides ready access to all track menus.

To show the track control, click the track control button  on the [toolbar](#).

5. Selecting a track

Tracks can be marked or edited only when they are selected. The track button of the currently selected track is displayed on the lower tier of the [toolbar](#).



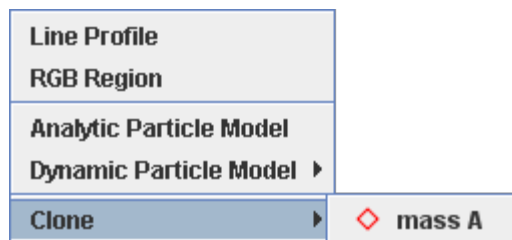
To select a different track, click its track button on the [track control](#) or select one of its steps in the video view.



To deselect all tracks, double-click the video or background mat.

6. Cloning, copying and importing tracks

Make a duplicate copy of an existing track using the Clone item in the Create menu or the Track|New menu.



Copy a track from one tab to another by selecting the track and copying it to the clipboard using the Edit|Copy menu item, then pasting using the Edit|Paste item.

Since the tape measure and axes are tracks, they can also be copied. When pasted, they replace the existing tape or axes in the tab. When no track is selected, the entire tracker panel (video clip, coordinate system and tracks) is copied.

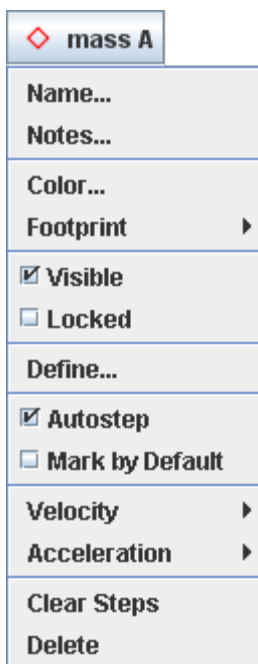
Tracks can also be imported directly from saved tracker files into an open tab using the File|Import menu item. For more information see [tracker files](#).


7. Customizing and documenting a track

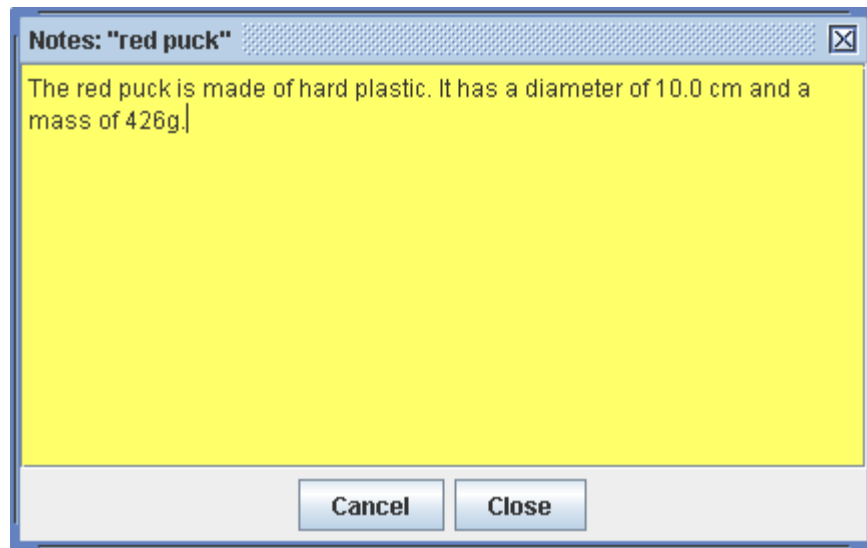
Every track is identified by its name, color, footprint (visible shape) and notes (descriptive comments). Newly created tracks are assigned default values for the first three properties that depend on the type of track. For example, a point mass might initially be named "mass A" and be drawn as a red diamond.



A track button showing the name, footprint and color of the track are displayed on the toolbar when the track is selected. To change the default values, click the track button and choose the Name..., Color... or Footprint item from the track menu.



To enter notes for a track, open the notes window by clicking the notes button  at the right end of the [toolbar](#). or choosing Notes... from the [track menu](#). As you enter information, the field turns yellow to indicate the changes have not yet been saved. To save the notes, click anywhere outside the window. To discard the changes, click the Cancel button.



8. Controlling visibility

Hide a track by turning off the Visible property in its [track menu](#). Or use the trails, labels, paths, positions, velocities and accelerations buttons on the [toolbar](#) to toggle the visibility of these features on all tracks.

9. Selecting and identifying points



To select a point, move the mouse cursor over it in the main video view. The cursor will become a hand pointer and the point will be identified in the bottom right message box. Click to select it. Note: To select a point while marking, release the shift key.

When a point is selected, its track is selected, its editable properties (position, etc) are displayed on the toolbar, and it is identified with a square selection icon.

10. Editing a step

To edit a step, select and drag one of its points. A selected point can also be nudged one pixel at a time with the arrow keys on the keyboard. Holding down the shift key increases the nudge distance.

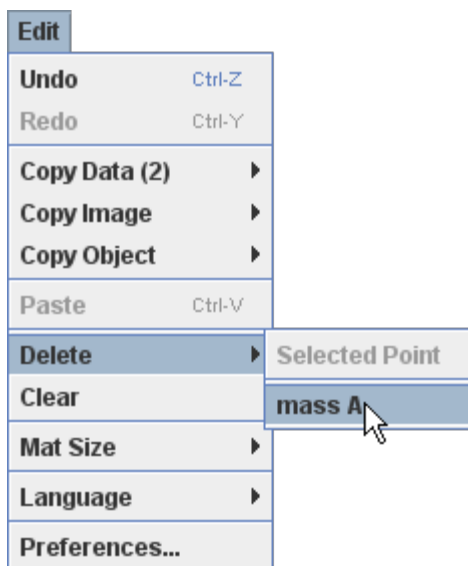
Many tracks also provide input fields on the toolbar for setting positions or other properties of the selected step.

11. Deleting

Delete a single step by selecting it and hitting the delete key on the keyboard. Delete all steps for a track by choosing the Clear Steps item from its [track menu](#).

Delete an entire track by name in the Edit|Delete menu or by choosing the Delete item in its [track menu](#).

Clear all tracks in the current tab by choosing the Edit|Clear menu item.



12. Locking a track

Locking a track prevents any changes to its steps. Lock a track by turning on the Locked property in its track menu.

Coordinate System

When you mark a point in Tracker's main video view, you are defining its image position. Image positions are measured in pixel units relative to the top left corner of the video image. In a 320 x 240 pixel image the upper left corner is at image position (0.0, 0.0) and the lower right is at (320.0, 240.0).

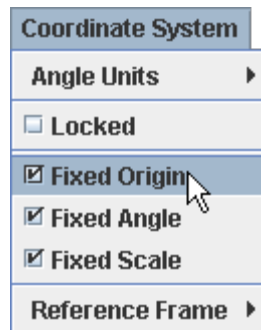
Since a video image is a camera view of the real world, a physical object within that image also has world coordinates. World coordinates are measured in scaled world units (e.g., meters) relative to a specified reference frame. The origin of the reference frame may be anywhere on or off the image.

The coordinate system is a set of transformations used to convert image positions into world coordinates. The coordinate system defines for each frame of the video:

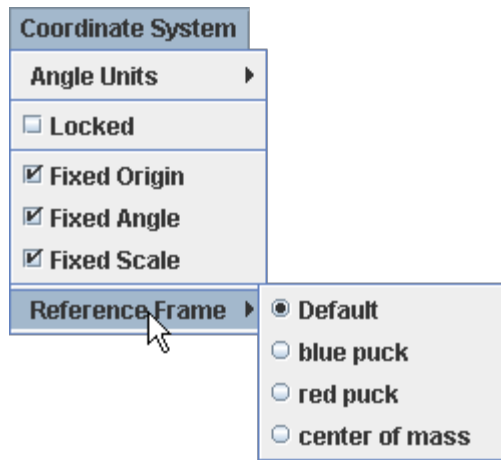
- scale (image units per world unit)
- origin (image position of the reference frame origin)
- angle (counterclockwise angle from the image x-axis to the world x-axis).

1. Setting coordinate system properties

By default, the scale, origin and angle of the coordinate system are fixed--that is, they do not vary from frame to frame. However, any or all of these may be allowed to vary by turning off the appropriate Fixed property in the Coordinate System menu on the menu bar.



The positions and properties of the origin that you set are those of the default reference frame. The Coordinate System|Reference Frame menu enables you to select other reference frames in which the origin moves along with a point mass, center of mass or particle model track. Center of mass reference frames are particularly useful when studying collisions.



2. Setting the scale (calibrating)

Set the scale using a [calibration stick](#) or [calibration points](#).

3. Setting the origin

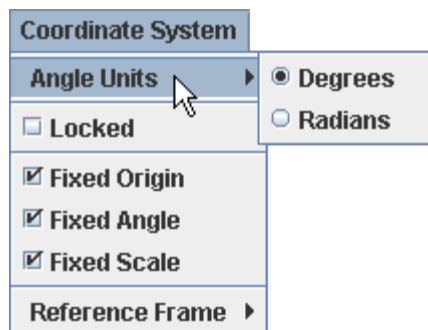
Set the position of the origin using the [axes](#), an [offset origin](#) or [calibration points](#).

4. Setting the angle

Set the angle of the x-axis using the [axes](#), [calibration stick](#) or [calibration points](#).

5. Setting angle units

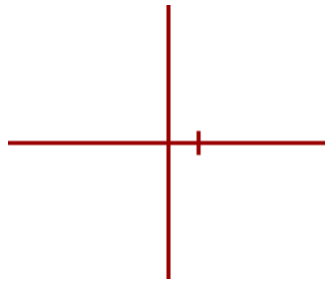
Angles can be displayed in either degrees or radians. Select the desired units from the Angle Units menu.



6. Locking the coordinate system

Locking the coordinate system prevents any changes to the scale, origin and angle. Lock it by turning on the Locked property in the Coordinate System menu.


Coordinate Axes



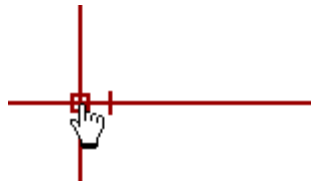
The coordinate axes show the location of the origin and direction of the positive x-axis of the coordinate system. The origin is at the intersection of the axes and the positive x-axis is indicated by a tick mark near the origin. The positive y-axis is always 90 degrees counter-clockwise from the positive x-axis.

Since the axes is a [track](#), it has a [track menu](#) that is accessible in the Tracks menu on the menu bar or by right-clicking the main video view.

1. Displaying the axes

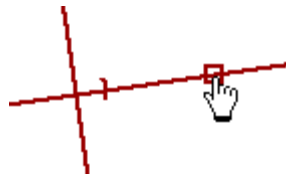
Display the axes by clicking the axes button  on the toolbar.

2. Moving the default origin



Select and drag or nudge the origin to a desired location in the main video view.

3. Setting the angle



Select and drag or nudge the positive x-axis to rotate the axes about the origin. Hold down the shift key to restrict angles to 5 degree increments.



The angle is displayed in the angle field on the toolbar. A desired angle may be entered directly in this field.

4. Locking the axes

Locking the axes prevents it from making any changes to the origin or angle. Lock the axes by turning on the Locked property in its [track menu](#).

Calibration Stick and Tape



The calibration stick and calibration tape are the most commonly used tools for calibrating the video scale--i.e., the ratio of the *world distance in meters* (or any desired length unit) to the *image distance in pixels* between two points. The world length of a calibration stick or tape is displayed in a readout and in a length field on the toolbar. For either tool, calibrating the video is simply a matter of setting this world length to a known value--see [Calibrating a video](#) for details.

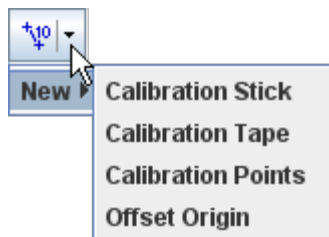
The difference between a calibration stick and a calibration tape is how its world length behaves when an end is dragged. For a calibration stick the *world length remains fixed* (thus changing the video scale). For a calibration tape the *world length changes* so that the video scale remains fixed. (The easiest way to understand this difference is to create both, place them side by side, and then for each drag an end and/or set the world length and observe the change in the other). The discussion below refers to a calibration stick but, except for this difference, applies to both tools.

A calibration stick or tape can also be used to [correct for tilt in the video image](#).

Since a calibration stick or tape is a [track](#), it has a [track menu](#) that is accessible in the Tracks menu on the menu bar or by right-clicking the main video view.

1. Creating and using a calibration stick or calibration tape

Click the arrow on the Calibration button on the toolbar and select New|Calibration Stick to create a new calibration stick. If desired, you can create more than one stick. Show or hide the calibration stick (along with other calibration tools, if any) by clicking the main part of the Calibration button.



The calibration stick or tape is initially placed near the center of the video image, and its world length is determined using the current scale. The world length and angle from the x-axis are displayed on the toolbar.



To change the world length, click the readout and enter the desired length in arbitrary units. Do not include the units when entering a world length. You can also enter a world length in the length readout on the toolbar.



To change the pixel length (and thus the scale), drag either end of the stick. To move the entire stick without changing the scale, drag the middle.



2. Calibrating a video

To calibrate a video, first drag the ends of the calibration stick to a video feature with known length (for example, a meter stick). Then click the readout to select it and enter the known length (but do *not* include units). For example, in the figures below a calibration stick is used to set the scale in meter units using a video image of a white PVC pipe with black stripes every 10 cm.



a. Drag the ends of the uncalibrated stick to the desired image positions



b. Click the readout to select it



c. Enter the known distance (in this case 0.3, since units are meters)



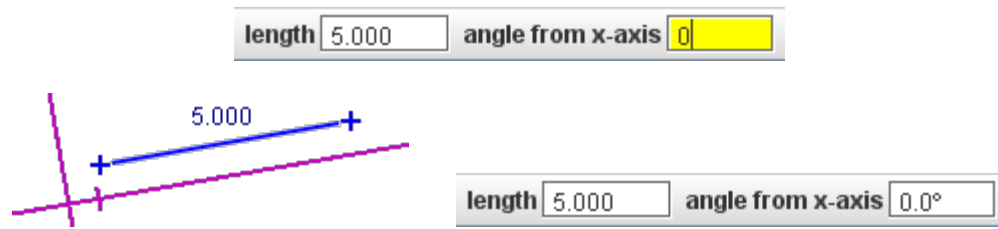
d. Completed calibration

3. Correcting for tilt in the video image

The calibration stick also displays its angle relative to the +x-axis on the toolbar. By setting this angle, you can correct for camera tilt when shooting a video.



To correct for tilt, drag the ends of the calibration stick so that it is parallel to a video feature that is known to be horizontal in the real world. Then enter an angle of zero into the angle field. This will rotate the +x-axis to the true horizontal. (Note: the same procedure can be used to set the +x-axis to any known angle.)



4. Unfixing the position

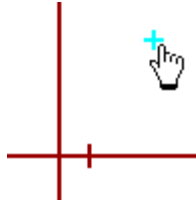
By default, the calibration stick has a fixed position--that is, its position is the same in all frames. Uncheck the Fixed Position checkbox in its [track menu](#) to allow the position to vary independently from frame to frame.

Note that unfixing the position of the calibration stick is not the same as unfixing the scale of the [coordinate system](#).

5. Locking the calibration stick

Locking the calibration stick prevents it from making any changes to the scale. Lock the stick by turning on the Locked property in its [track menu](#).

Offset Origin

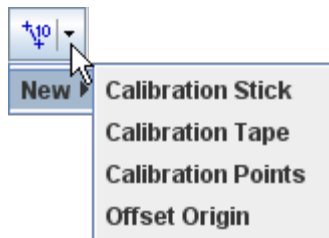


An offset origin is a point with user-settable world coordinates whose image position on the screen is determined by the video coordinate system. This is the opposite of a point mass step, which has a user-defined image position with world coordinates determined by the coordinate system.

When an offset origin is dragged in the main video view, the origin of the coordinate system moves with it in order to maintain the offset origin's assigned world coordinates. This makes it useful for remotely setting the position of the origin, particularly when the origin is outside the video image.

1. Creating an offset origin

Click the arrow on the Calibration button on the toolbar and select New|Offset Origin to create a new offset origin. If desired, you can create more than one. Show or hide the offset origins (along with other calibration tools, if any) by clicking the main part of the Calibration button.



The offset origin is initially unmarked and the toolbar indicates this status in red. Shift-click the video to mark the offset point. The x- and y-components (world coordinates) of the newly marked point is displayed on the toolbar.



Once the offset origin is created and marked, you can [re-mark it](#), [change its world coordinates](#) or [move it](#) to a new image position as described below.

2. Re-marking the point

Select the offset origin and shift-click again to move it to a new location without changing the coordinate system.

3. Changing the world coordinates (moves the origin)



x	30.00	y	40.00
---	-------	---	-------

Select the offset origin and enter the desired values in the x and y fields on the toolbar to change its world coordinates.

Note: changing the world coordinates of an offset origin moves the coordinate system origin so that the offset origin's image position remains unchanged.

4. Moving the offset origin (moves the origin)

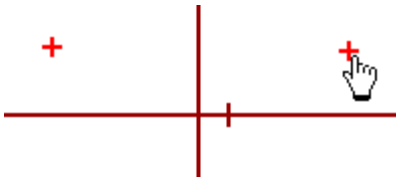
Select and drag or nudge the offset origin to a desired location in the main video view.

Note: moving an offset origin moves the actual coordinate system origin with it so that the offset origin's world coordinates remain unchanged.

5. Locking the offset origin

Locking the offset origin prevents it from making any changes to the origin. Lock the offset origin by turning on the Locked property in its [track menu](#).

Calibration Point Pair

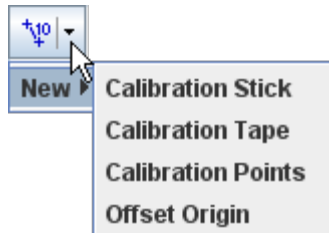


A calibration point pair track is similar to an [offset origin](#) except that it defines two points with fixed (settable) world coordinates. World coordinates may consist of an x-component, y-component or both. For a given coordinate system, these world coordinates uniquely determine the scale, origin, and/or angle at each step. When either of the calibration points is dragged in the main video view, the properties of the coordinate system are modified in order to maintain the assigned world coordinates. Calibration points are the easiest way to set coordinate system properties when two features with known world coordinates are visible in all video frames.

Note: Calibration points are very powerful. It is strongly recommended to "play" with some calibration points while both the axes and calibration stick are visible to see how they work together to control the coordinate system.

1. Creating calibration points

Click the arrow on the Calibration button on the toolbar and select New|Calibration Points to create a new calibration point pair. If desired, you can create more than one pair. Show or hide the calibration points (along with other calibration tools, if any) by clicking the main part of the Calibration button.

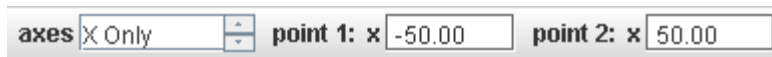


The calibration points are initially unmarked and the toolbar indicates this status in red. Shift-click the video to mark the first point, then do the same for the second. The x- and y-components (world coordinates) of the newly marked points are displayed on the toolbar.

+	calibration points A	axes	<input type="text" value="XY"/>	point 1: shift-click to mark
+	calibration points A	axes	<input type="text" value="XY"/>	point 1: x <input type="text" value="-100.0"/> y <input type="text" value="40.00"/> point 2: shift-click to mark
+	calibration points A	axes	<input type="text" value="XY"/>	point 1: x <input type="text" value="-100.0"/> y <input type="text" value="40.00"/> point 2: x <input type="text" value="80.00"/> y <input type="text" value="20.00"/>

Once the calibration points are created and marked, you can [re-mark them](#), [change their world coordinates](#) or [move them](#) to new image positions as described below.

2. Axis options

A toolbar interface showing a spinner labeled 'axes' with 'X Only' selected. To its right are two input fields: 'point 1: x' with the value '-50.00' and 'point 2: x' with the value '50.00'.

The "Axes" spinner determines whether the calibration points control both x- and y-axes or only a single axis. When a single axis is selected (here "X Only"), moving a calibration point along that axis changes the scale and translates the origin without changing the angle. Moving a calibration point perpendicular to the selected axis has no effect. This is very useful when one axis is unknown or unimportant--for example, with vertical motion studies or optical spectrum analysis using a [line profile](#) track.

3. Re-marking a calibration point

Select either calibration point and shift-click again to move it to a new location without changing the coordinate system.

4. Changing the world coordinates of a calibration point

A toolbar interface showing two input fields for world coordinates: 'x' with the value '30.00' and 'y' with the value '40.00'.

Enter the desired values in the x and/or y fields on the toolbar to change the world coordinates of the selected calibration point.

Note: Changing the world coordinates changes the coordinate system scale, origin and/or angle so that the image positions of both points remain unchanged.

5. Moving a calibration point

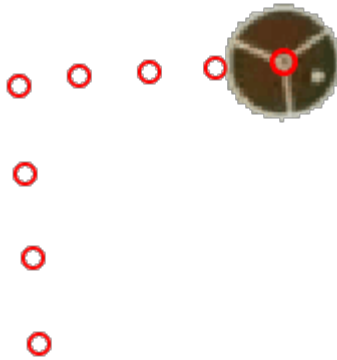
Select and drag or nudge either calibration point to a desired location in the main video view.

Note: Moving a calibration point changes the coordinate system scale, origin and/or angle so that the world coordinates of both points and the image position of the unselected point remain unchanged.

6. Locking the calibration points

Locking the calibration points track prevents it from making any changes to the coordinate system. Lock the calibration points track by turning on the Locked property in its [track menu](#).


Point Mass



A point mass track represents a mass moving as a point-like object. It is the most fundamental model of a moving inertial object. Point masses are the building blocks with which more complex and realistic models of physical systems are constructed in classical physics.

1. Marking and editing the steps

- A. Manual tracking: shift-click once to mark a step at the mouse position, or shift-enter to mark a step at the exact location of the previous step. The video will autoadvance for easy and fast marking. It is wise to set the [video clip](#) properties first so you don't mark unnecessary video frames. Zoom in for accuracy.
- B. Autotracking: point mass tracks can be automatically marked as long as the feature of interest has a consistent shape, size, color and orientation. Please see [Autotracker](#) for more information.

Point masses have visible trails by default. Hide or shorten the trails if desired using the trails button  on the [toolbar](#).

To edit a marked step, select it and drag or use the arrow keys on the keyboard to nudge it one pixel at a time. Very fine control is possible at a high zoom level. You can also enter world coordinates directly in the toolbar fields to assign a known position.

step 1 (0.100s)	x	<input type="text" value="2.190"/>	y	<input type="text" value="1.060"/>	r	<input type="text" value="2.433"/>	theta	<input type="text" value="25.8°"/>
-----------------	---	------------------------------------	---	------------------------------------	---	------------------------------------	-------	------------------------------------

2. Setting the mass

m	<input type="text" value="0.5"/>
---	----------------------------------

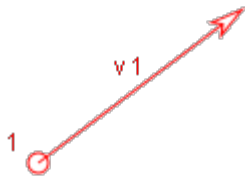
A newly created point mass is given a default mass of 1.0 (arbitrary units). Enter a new mass ($m \geq 0$) in the mass field on the toolbar to change it.


3. Displaying motion vectors

Toggle the vector visibility for all point masses by clicking the velocity button  or acceleration button



on the [toolbar](#). The vectors are initially attached to their positions (i.e. the tail of the velocity vector for step n is at the step n position).



Note: Some motion vectors, especially accelerations, may be very short. You can artificially "stretch" them by clicking on the stretch button  on the [toolbar](#) and selecting a stretch factor from the dropdown menu.

You can change the footprint of a point mass motion vector using the footprint item on its [track button](#). The "big arrow" footprint is particularly useful for large classroom presentations.

4. Analyzing motion vectors

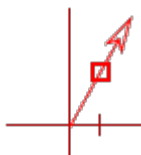
Select a vector by clicking near its center to display its components on the toolbar.

step v 1 (0.100s)	vx	1.020E3	vy	775.0	v	1.281E3	theta	37.2°
-------------------	----	---------	----	-------	---	---------	-------	-------

Drag a vector to detach it from its position and move it around. Drop the vector with its tail near its position to reattach--it will snap to the position.




A vector will also snap and attach to the origin when the axes are visible. This is useful for estimating and visualizing its components.



Attach all vectors quickly to the origin or positions with the Tails to Origin or Tails to Position items in the point mass track menu.

5. Displaying momentum and net force vectors

Click the dynamics button  on the [toolbar](#) to multiply all velocity and acceleration vectors by their mass. This changes them to momentum and net force vectors, respectively.

6. Linking motion vectors

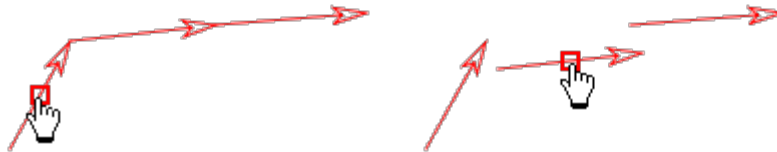


Vectors can be linked tip-to-tail to visually determine their vector sum. To link vectors, drag and drop one with its tail near the tip of the other. The dropped vector will snap to the tip when it links. You may continue to link additional vectors in the same way to form a chain.

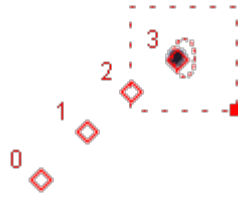


Note: Tracker makes no attempt to check whether it is mathematically appropriate or physically meaningful to link a given set of vectors--it simply makes it possible.

When you drag the first vector (i.e. the vector with the unlinked tail) in a chain, the chain moves as a unit and the vectors remain linked. When you drag any vector further up the chain, however, it detaches and "breaks" the chain.




Autotracker



When a video feature of interest has a consistent shape, size, color and orientation in all video frames, it can be tracked automatically using autotracker. This eliminates the need to mark each frame manually with the mouse, thus speeding up the tracking process and producing more consistent data.

Tip: an excellent way to obtain videos suitable for autotracking is to stick colored circular markers on the objects of interest (a white ring around a colored center is even better). Multiple objects can be autotracked if a different color is used for each.

Click the autotracker button  on the toolbar to show or hide autotracker.

1. How autotracker works

Autotracker works by creating one or more template images of a feature of interest and then searching each frame for the best match to that template. The best match is the one with the highest match score, a number that is inversely proportional to the sum of the squares of the RGB differences between the template and match pixels. Once the best match is found, it is compared with nearby match scores to determine an interpolated sub-pixel best match position.

By default, the template evolves to adapt to shape and color changes over time. Higher evolution rates track more rapid changes, but may result in template "drift" over many frames.

A target defines the position at which points are marked relative to the template when matches are found. The target may be offset from the template. The specific track and point marked at the target position must be selected prior to autotracking.

A video frame in which a template and its associated target are defined is called a key frame. Autotracking requires at least one key frame, but additional key frames may be defined to track sudden or extreme changes in the object, background or illumination.

When the best match score is high (a good match), a point is automatically marked at the target position. But when the match score is only moderate (a possible match) then the user is asked to review the match and accept or override it. The automark level for automatic marking may be set by the user.

Autotracker limits its search for a match in each frame to a user-defined rectangular search area. When at least two steps have been marked, the velocity and acceleration of the point mass is used by default to predict the location of future matches and the search area is moved accordingly. However, you can turn off this look ahead feature and/or reposition or resize the search area at any time.

You can also limit the search to the x-axis only for 1D autotracking. Set the axis origin and tilt angle to search along any desired line.

After autotracker has completed the marking process, you may modify the steps at will. In other words, autotracker helps you mark the steps but does not limit your control over them.

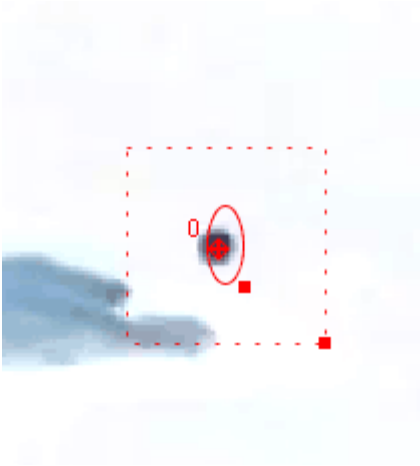
2. Preparing to use autotracker

Before using autotracker, scan through the video and verify that the feature of interest is visible and reasonably consistent (shape, size, color and orientation) in all frames. If not, adjust the [video clip](#) start frame, end frame and/or step size until this condition is met. Then reset the video to the start frame.

3. Using autotracker

1. Select the target track.
2. Shift-control-click the video feature of interest to create a key frame. This will display autotracker if it is not already visible.
3. Change the default settings if desired.
4. Click the Search button.

Figure 1 shows autotracker after creating a key frame. The template is outlined on the video and shown at 2x magnification in autotracker along with the (perfect) match found. The target point is indicated by a bold cross on the video and the search area is outlined with a dashed line.



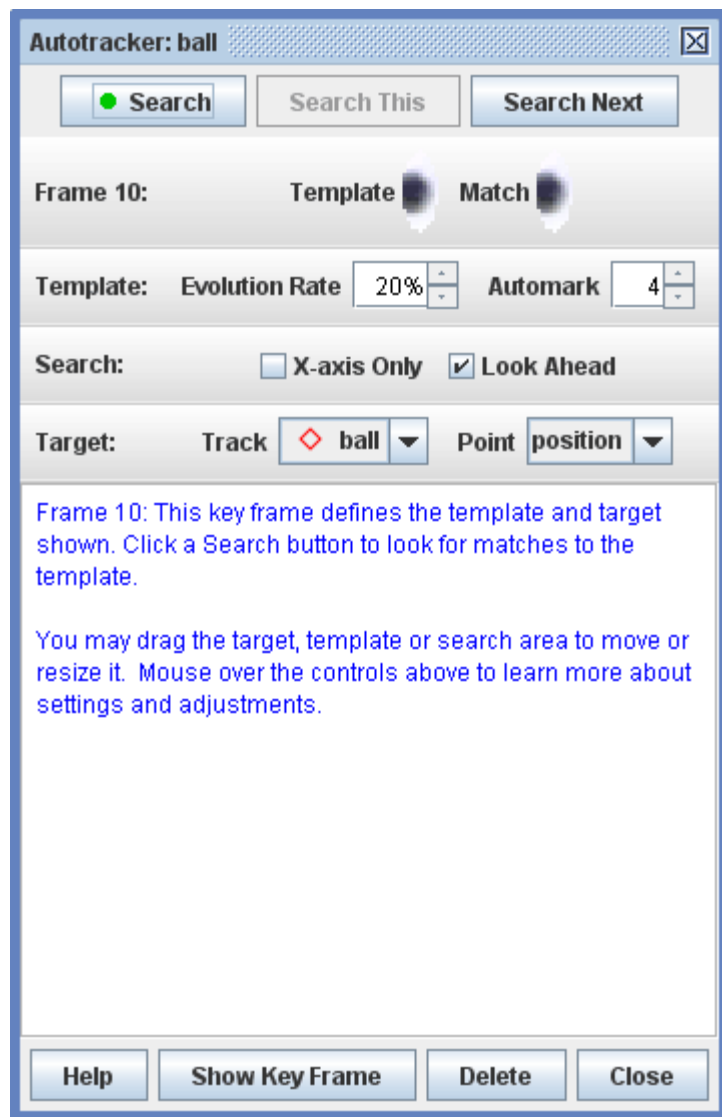


Fig. 1 Autotracker

4. Settings and controls

Controls are organized into the following categories. To learn more about a specific control or setting, simply move the mouse over it.

Search buttons:

1. The Search button steps through the video, searching and marking each frame as it goes.
2. The Search This button is used to search the current frame only. It is often used to repeat a search after adjusting the search area if a match is not found on the first pass.
3. The Search Next button makes a single step forward, searches that frame, and stops. It is useful when you want to review each match before moving on to the next.

Template: The template is the image to be matched.

1. Move or resize the template by dragging its center or handle (small solid square), respectively. Tip: the template need not be large nor include the whole object. A feature that is unique and includes high-contrast edges generally works best.

2. Set the evolution rate to define how the template adapts to shape and color changes. An evolution rate of 0% does not evolve at all (constant template image) while an evolution rate of 100% completely replaces the template with the match image after each frame. Intermediate evolution rates overlay the match image onto the current template with the indicated opacity. Note: higher evolution rates track more rapid changes, but may result in template "drift" over many frames.
3. Set the automark level to define the minimum match score needed for automatic marking. The default level of 4 is recommended as a good starting point. Tip: low automark levels can result in false matches--try increasing the evolution rate or defining additional key frames instead.

Search: The search area defines the region that is searched for the best match.

1. Move or resize the search area by dragging its center or handle (small solid square), respectively. Tip: The search area need not be large. For many motions the look-ahead feature does a good job of predicting match positions and searching in the right place.
2. Check the X-axis Only checkbox to limit the search to the x-axis only. The coordinate system origin will automatically be set to the center of the template. Tilt the axes to search in the desired direction. Note: if the x-axis does not pass through or near the center of the search area, no matches will be found.
3. Check the Look Ahead checkbox to automatically move the search area to predicted match positions using a look-ahead algorithm that assumes constant acceleration. When this option is unchecked, the search area is moved to the previous match position.

Target: The target defines both the track and point to be marked and the position of the mark relative to the template.

1. Select the target track and point from the drop-down lists.
2. Move the target by dragging it.

Other buttons:

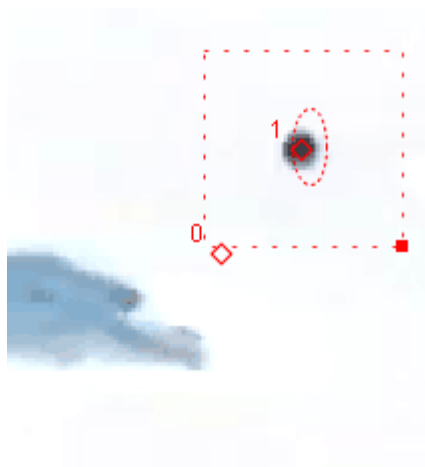
1. The Help button shows this help file.
2. The Show Key Frame button enables you to quickly jump to a key frame to review and/or change the template or target.
3. The Delete button enables you to easily delete incorrectly marked points.
4. The Close button closes autotracker.

5. Search results

After searching a frame, autotracker will display one of the following search results and, in some cases, present options for solving problems.

1. A good match was found (match score above the automark level) and marked automatically (Figure 2).
2. A possible match was found. Options include accepting the match, marking the point manually (shift-click), making changes and repeating the search, or moving on to the next frame (Figure 3).
3. No match was found. Options include marking the point manually (shift-click), making changes and repeating the search, or moving on to the next frame.

4. Unable to search. This can happen if the search area falls outside the video image or, for 1D tracking, the x-axis does not pass through the search area. Options include marking the point manually (shift-click), making changes and repeating the search, or moving on to the next frame.



Autotracker: ball

Frame 11: Template Match

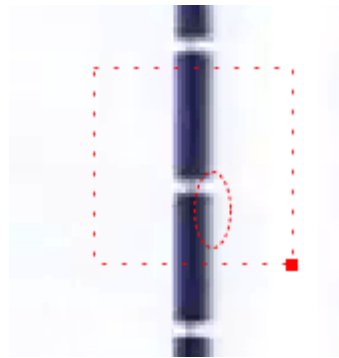
Template: Evolution Rate Automark

Search: ☐ X-axis Only ☒ Look Ahead



Target: Track Point

Frame 11 (match score 44.2): The match was marked automatically.

Fig. 2 Search results: good match



Autotracker: ball

Frame 17: Template  Match 

Template: Evolution Rate Automark

Search: ☐ X-axis Only ☒ Look Ahead

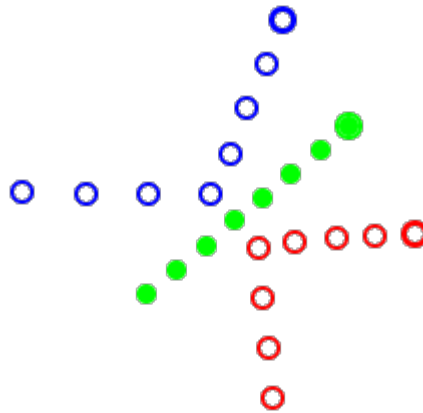
Target: Track Point

Frame 17 (match score 2.6): A possible match was found in the search area shown. Your options are:

- accept the match
- move the search area and search again
- skip this frame and continue with the next
- shift-click to mark the step manually
- step back and change the evolution rate or shift-control-click to define a new key frame

Fig. 3 Search results: possible match (false match in this case)

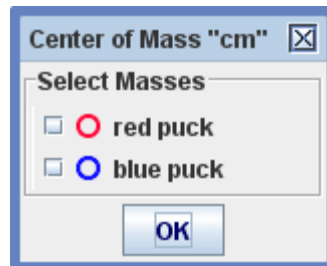
Center of Mass



A center of mass (cm) track represents the center of mass of a collection of point masses. Its mass is not settable, but instead is the sum of its point masses. Similarly, its steps are not marked but instead are determined by the positions and masses of its point masses. Center of mass footprints are always solid to distinguish them from independent point masses.

A cm is itself a point mass with the usual motion vectors. See [point mass](#) for additional information.

1. Adding point masses to a cm



Select the point masses to include in a cm by checking them in the dialog shown. The dialog is displayed when the center of mass is initially created or by choosing Select Masses in the cm's [track menu](#).

Vector



A vector track can represent any vector but is commonly used as a force in a force diagram. Since it is a track, the force may vary with time (i.e. with step number).

Note: Many introductory physics topics involve constant forces or forces at a single instant of time. By defining a [video clip](#) with a single frame and using vector and [vector sum](#) tracks, these situations can be modeled and analyzed visually using Tracker. The background video can be a single frame of a movie, a still image or a blank white screen.

1. Marking the steps

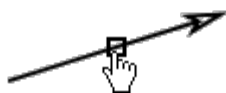


Shift-click the crosshair cursor at the tail and drag the tip with the hand cursor to mark a vector step. Vectors are drawn with solid lines to distinguish them from motion vectors.

You can also shift-enter instead of using the mouse to mark a vector step that is identical to the previous step.

Vectors have visible trails by default. Hide or shorten the trails if desired using the trails button on the [toolbar](#).

2. Editing a vector



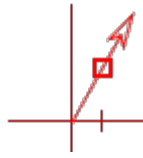
Select any point on a vector to display its components on the toolbar. Enter a desired value in the appropriate field or select and drag/nudge the tip to change the components.

t	0.000	x	4.595	y	1.971	mag	5.000	theta	23.2°
---	-------	---	-------	---	-------	-----	-------	-------	-------

Drag or nudge the center of a vector to move it without changing its components.

3. Analyzing vectors

When the axes are visible you can drop a vector with its tail near the origin and it will snap and attach to the origin. This is useful for estimating and visualizing its components.



Attach all vectors quickly to the origin with the Tails to Origin menu item in the vector track menu.

4. Linking vectors (see also [vector sum](#))



Vectors can be linked tip-to-tail to visually determine their vector sum. To link vectors, drag and drop one with its tail near the tip of the other. The dropped vector will snap to the tip when it links. You may continue to link additional vectors in the same way to form a chain.

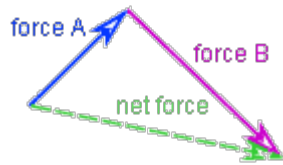


Note: Tracker makes no attempt to check whether it is mathematically appropriate or physically meaningful to link a given set of vectors--it simply makes it possible.

When you drag the first vector in a chain of linked vectors, the chain moves as a unit and the vectors remain linked. When you drag any vector further up the chain, however, it detaches and "breaks" the chain.



Vector Sum

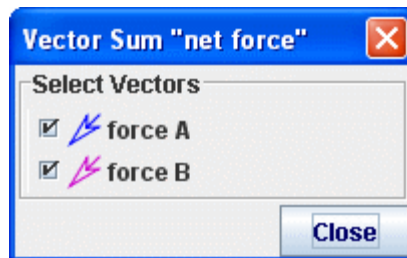


A vector sum track represents the vector sum of a collection of vector tracks. It's steps are not marked but instead are determined by the components of the vectors in the sum.

A vector sum is drawn with a dashed line to distinguish it from vector tracks and motion vectors. See [vector](#) and [point mass](#) for additional information.

Note: adding vectors with a vector sum is not the same as [linking vectors](#) tip-to-tail. Any two vectors can be linked, including vectors that are different steps in the same track. But adding vectors in a vector sum requires two or more separate vector tracks. The vector sum track consists of a vector at each step that is the sum of the corresponding steps in the vector tracks being added. In the image above, the force A and force B vectors have been linked tip-to-tail to illustrate graphically how the net force vector is determined, but the net force would be the same even if the two force vectors were dragged apart to unlink them as long as their components were not changed.

1. Adding vectors to a vector sum



Select the vectors to include in a sum by checking them in the vector sum dialog. The dialog is displayed when the vector sum is initially created or by choosing Select Vectors in the vector sum's [track menu](#).

Line Profile



A line profile track is a tool for measuring brightness and rgb data along a line on a video image. If the line width is increased by adding spread, image pixels above and below the line are averaged in order to reduce noise and/or increase sensitivity.

1. Marking the line



Click and drag the mouse (crosshair cursor) to mark a line profile. The line is drawn as a narrow rectangle that surrounds the pixel points analyzed by the line profile tool.

Drag either end of the line to change its length. Drag the center of the line to position it.

2. Adding spread



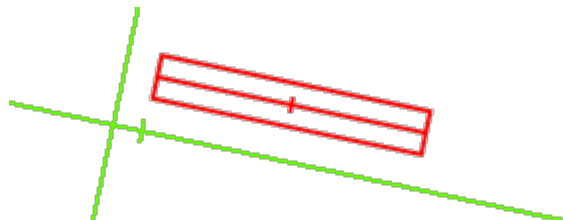
To increase the number of pixels sampled for a smoother average you can give the line profile a spread. Select the line and enter the desired spread in pixels in the field on the toolbar.

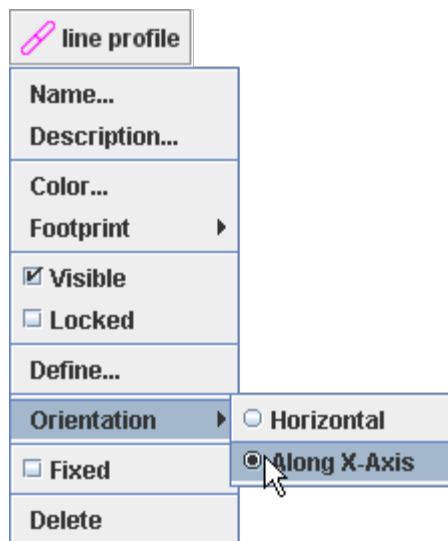
The spread pixels extend to both sides of the line. Thus, for a given data point on the line, the total number of pixels sampled (i.e., width of the line profile) is $1 + 2 \times \text{spread}$. The outline of the line profile shows all pixels included in the average.



3. Line orientation

By default, a line profile has a horizontal orientation--that is, parallel to the top or bottom edge of the video image. Setting an x-axis orientation by selecting the Along X-Axis item in its track menu will instead cause the line to remain parallel to the x-axis. This is useful when measuring spectra that have been inadvertently captured with a tilted camera, for example.





4. Unfixing the line

By default, the line profile has a fixed position--that is, its center position and length are the same in all frames. Uncheck the Fixed Position checkbox in its [track menu](#) to allow these properties to vary independently from frame to frame.

RGB Region



An rgb region track measures the mean brightness and rgb data as a function of time in a circular region of a video image.

1. Marking the rgb region

Click the mouse (crosshair cursor) to mark the center of the rgb region. The region is drawn as a circle around a center cross. Drag the center of the region or select it and enter the desired world coordinates in the toolbar fields to position it.

If the position of the rgb region is unfixed so that it varies from frame to frame (see below), then the video will autostep forward so the region can be marked independently on every frame. Even though the region is automatically drawn on every frame, you can still hold down the shift key and click the mouse to move it immediately to the clicked position.

2. Unfixing the position and/or radius

By default, the rgb region has both a fixed position and a fixed radius--that is, its position and radius do not vary from frame to frame. Uncheck the appropriate checkbox in its track menu to allow these properties to vary.

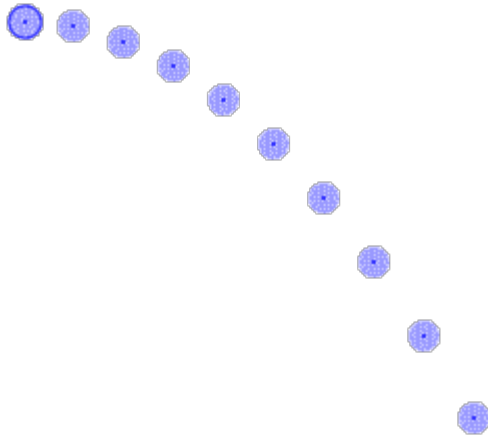
3. Setting the radius



Select the region and enter the radius in pixels in the field on the toolbar. The outline of the region shows the pixels included in the average. If the region's radius is unfixed, you can set a different radius in every frame.



Particle Models



A particle model track is a mathematical model of a point mass. The step positions of the particle are determined by the parameters of the model rather than being marked with the mouse.

There are two types of models: analytic and dynamic. An analytic model defines position functions of time ([Figure 4](#)), while a dynamic model defines force functions and initial conditions for numerical ODE solvers ([Figure 1](#)). Dynamic models may be defined in either cartesian or polar coordinates.

Models have a start and end frame that define the frames of the video in which they are drawn. This makes it possible to define multiple models that apply at different times in the same video.

A particle model has a settable mass and generates motion data and vectors just like any other point mass. See [point mass](#) for additional information.

1. Building models

Particle model properties are displayed and edited using the Model Builder tool. To use the builder, choose Model Builder... from the model's track menu.

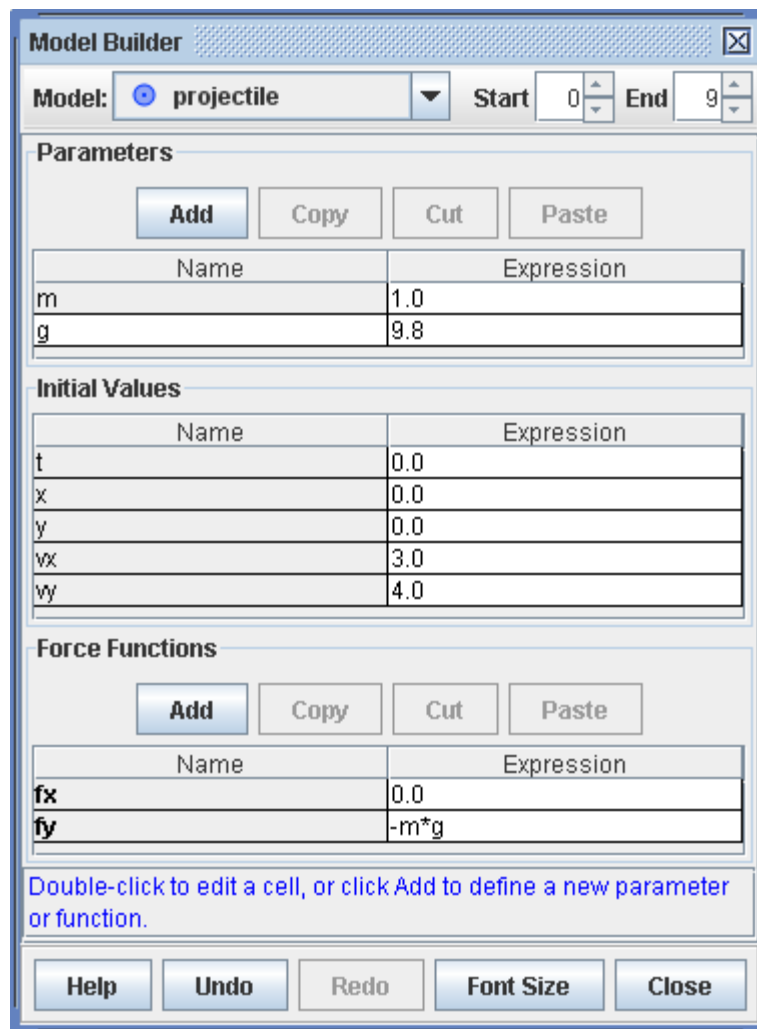


Fig. 1 Model Builder with a dynamic model of a simple projectile

Functions and parameters are defined by entering expressions that are "parsed" (interpreted) by the OSP parser. The values of parameters are constants while those of functions depend on input variables such as x , y , t , etc. The parser recognizes the following elements:

- Numbers in decimal or scientific notation (e.g., $1.0\text{E-}3$)
- Names of parameters, functions and other input variables
- Constants e and π
- Arithmetic operators $+$ $-$ $*$ $/$ $^$
- Boolean operators $=$ $>$ $<$ \leq \geq $<=>$ $\&$ $!$
- Parentheses to control order of operation
- Mathematical functions shown in Table 1
- If statements in the form *if(conditional statement, expression1, expression2)*. Expression1 is evaluated if the conditional statement is true and expression2 is evaluated if it is false. For example, if $(x < 0, x^2, -x^2)$ is a valid function expression.

abs(x)	acos(x)	acosh(x)	asin(x)	asinh(x)	atan(x)	atanh(x)	atan2(x,y)	ceil(x)	cos(x)
cosh(x)	exp(x)	frac(x)	floor(x)	int(x)	log(x)	max(x,y)	min(x,y)	mod(x,y)	random(x)
round(x)	sign(x)	sin(x)	sinh(x)	sqr(x)	sqrt(x)	step(x)	tan(x)	tanh(x)	

Table 1 Mathematical functions recognized by the OSP Parser

Model Builder displays model functions along with associated parameters and initial conditions in tables with Name and Expression columns as shown in Fig. 1. The name of the model is shown in a spinner field above the tables.

To edit a name or expression, double-click its table cell (gray cells cannot be edited). Names must be unique and can contain no spaces or mathematical symbols. Expressions must be valid mathematical expressions parsable by the OSP parser.

To create a new parameter or support function, click the appropriate Add button.

When editing an expression, the names of all available variables are listed in blue directly under the popup editor as shown in Fig. 2. To insert a variable directly from the list, move the mouse cursor over it until it turns red and then click.

Variables for parameter expressions include only other parameters, while variables for function expressions include independent variables (e.g., x , y , t , etc), parameters and support function names. In the example shown, the "fy" function may depend on any or all of the variables x , v_x , y , v_y , t , m , g . The entry $-m*g$ is thus a valid expression.

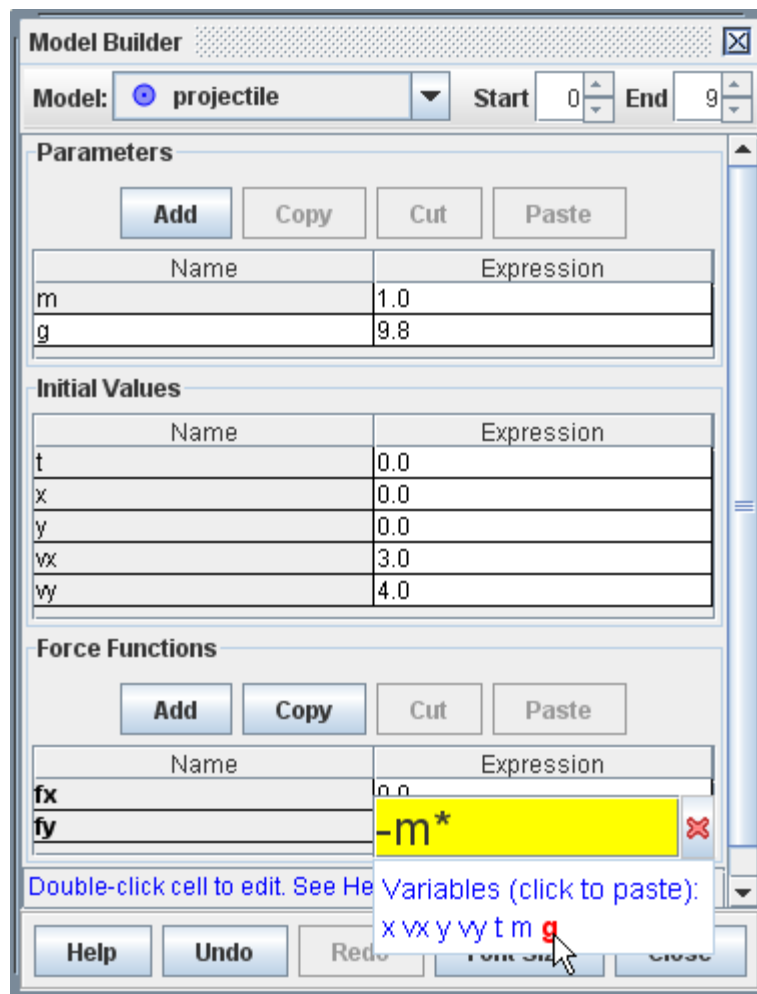


Fig. 2 Editing an expression

If an invalid expression is entered into a cell the cell turns red and an error message is displayed in the status

bar. In Figure 3, the expression "-mg" is invalid since the multiplication operator (*) has been omitted. Circular references also result in an error condition.

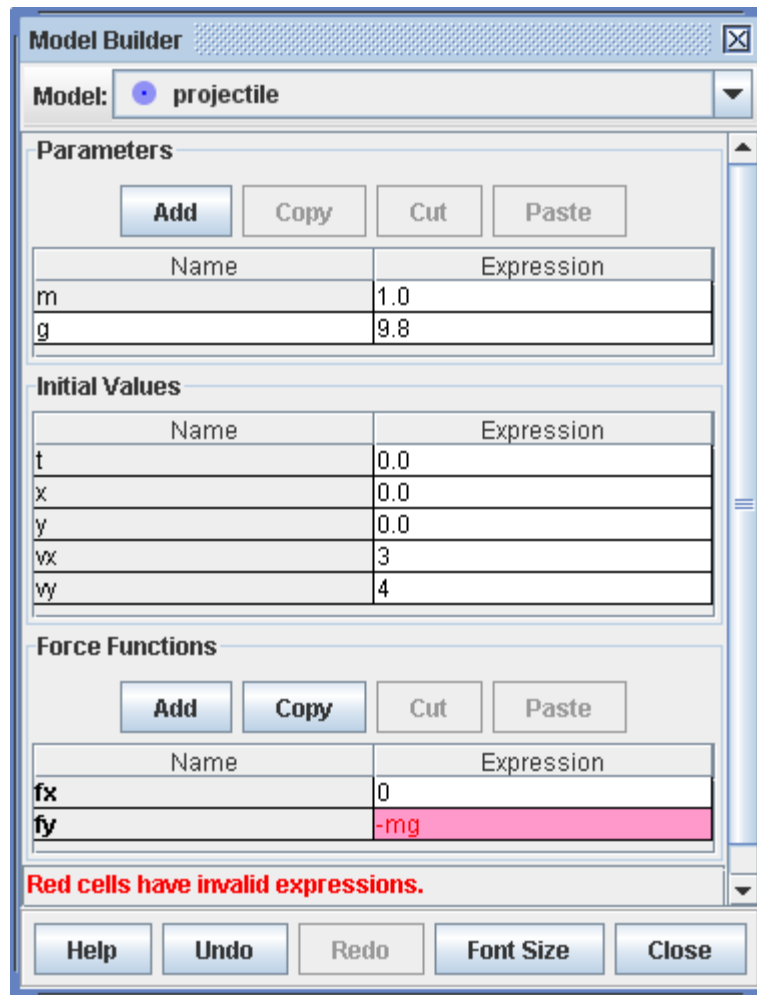


Fig. 3 Invalid expression

Model Builder includes several features designed to help build, modify and compare models quickly:

1. Complex expressions can be simplified by defining one or more support functions. For example, the analytic model of a damped oscillator shown in Fig. 4 defines the support function "amp" that represents the exponentially decaying amplitude. This makes the y-position function easier to write and understand.
2. All edits are undoable and redoable making it easy to quickly flip back and forth between two function expressions or parameter values.
3. Single or multiple table rows can be copied or cut to the clipboard for pasting into other Model Builder tables.

Model Builder [X]

Model: ● damped

Parameters

Add Copy Cut Paste

Name	Expression
m	0.4
k	10
omega	$\sqrt{k/m}$
A	1.0
b	5.0×10^{-2}

Initial Values

Name	Expression
t	0.0

Position Functions

Add Copy Cut Paste

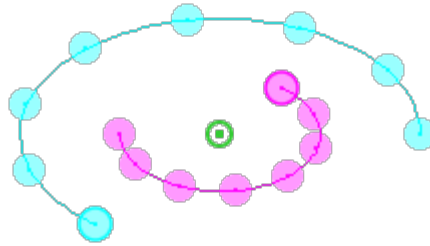
Name	Expression
x	0
y	$\text{amp} \cdot \sin(\omega \cdot t)$
amp	$A \cdot \exp(-b \cdot t)$

Double-click to edit a cell, or click Add to define a new parameter or function.

Help Undo Redo Font Size Close

Fig. 4 Using a support function to simplify expressions

Two-Body System



A two-body system track models a system of two [dynamic particles](#) that interact with each other via internal radial and tangential forces. The mass of the system is the sum of the particle masses, and the position of the system is the center of mass of the particles.

The internal forces are functions of the distance r between the particles and the angle θ from particle 1 to particle 2. Internal forces act on both particles in the system but in opposite directions (as required by Newton's third law). Internal forces are defined using the Model Builder as shown in [Figure 4](#).

Each of the particles in the system can also experience independent external forces. External forces are also defined using the Model Builder as shown in [Figure 5](#).

A two-body system generates motion data and vectors just like any other point mass. See [point mass](#) for additional information.

1. Defining the particles in a system

When a two-body system is first created, a dialog is displayed that identifies the particles in the system and provides buttons to change them. The dialog can be recalled at any time by choosing Select Particles... from the system's track menu.

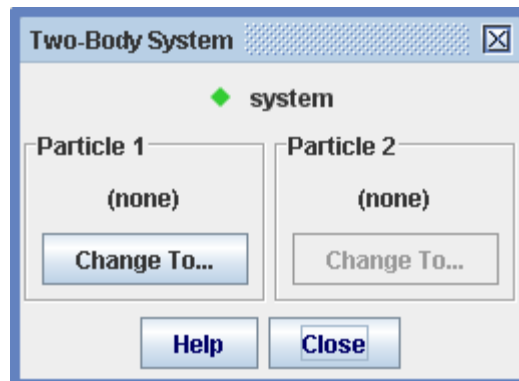


Fig. 1 Empty two-body system

A new system is initially empty. To add a particle to the system, click the button and create a new particle model (you can also choose a previously created particle as shown in Figure 3).

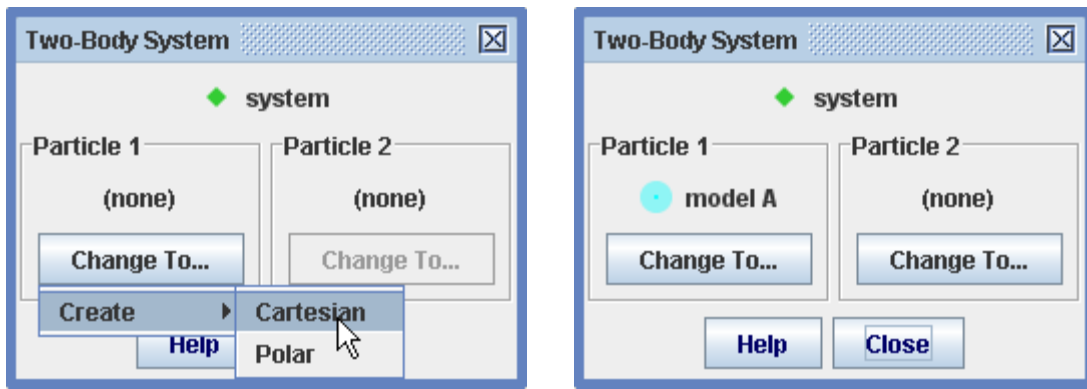


Fig. 2 Adding a new particle to the system

Repeat the above to add a second particle. You can also replace a system particle with another new or existing particle as shown in Figure 3.

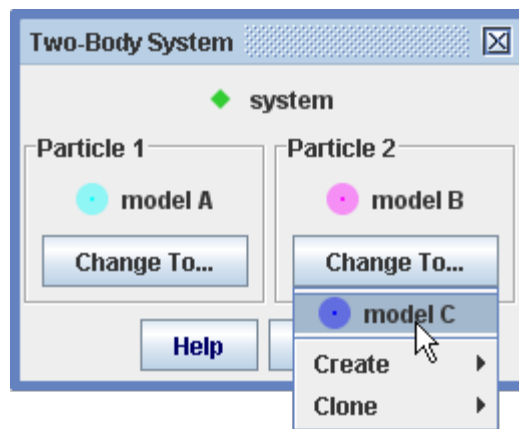


Fig. 3 Replacing a particle in the system

2. Defining the internal forces for a system

The internal forces and other properties of a two-body system are displayed and edited using the Model Builder tool. See [building models](#) for detailed information on the Model Builder.

Select the two-body system from the Model Builder drop-down list to display its properties. Note that the masses of the system particles are included in the parameter list, so they are available for use in force expressions. The masses and initial relative positions and velocities are not editable since they are determined by the particles themselves.

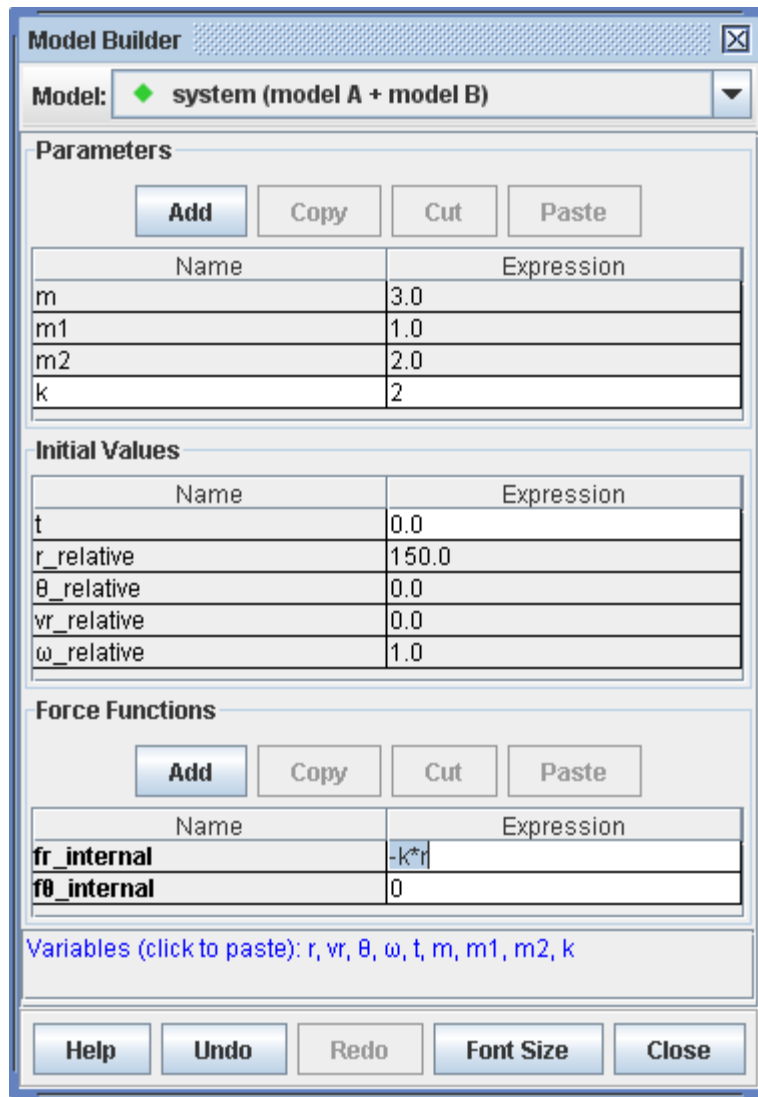


Fig. 4 Model Builder for a two-body system with an internal elastic force

3. Defining the external forces on the particles

The external forces and other properties of the individual particles in a system are also displayed and edited using the Model Builder tool. See [building models](#) for detailed information on the Model Builder.

Select a particle of interest from the Model Builder drop-down list to display its properties. Note that all properties, including the mass and initial positions and velocities, are editable.

Model Builder [X]

Model: ● model A (in system) ▼

Parameters

Add Copy Cut Paste

Name	Expression
m	1.0

Initial Values

Name	Expression
t	0.0
x	100
y	0.0
vx	0.0
vy	100

Force Functions Valid expression

Add Copy Cut Paste

Name	Expression
fx	0
fy	0

[Double-click cell to edit. See Help for valid expressions.](#)

Help Undo Redo Font Size Close

Fig. 5 Model Builder showing a particle model with non-zero initial position and velocity but no external forces

Tape Measure




A tape measure is used for measuring distances and angles. The world (scaled) length of the tape is displayed in a readout and in a length field on the toolbar. The angle of the tape relative to the +x-axis is displayed only on the toolbar.



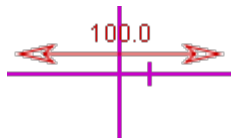
Since a tape measure is a [track](#), it has a [track menu](#) that is accessible in the Tracks menu on the menu bar or by right-clicking the main video view.

A calibration tape is a tape measure which can be used to calibrate the video scale. For more information, see [calibration stick](#).

1. Creating and using a tape measure

To create a tape measure, click the Create button  and choose Measuring Tools|Tape Measure from the popup menu. You can create as many as you need.

The new tape measure is initially placed slightly above the center of the video image.



To measure distances, drag either end of the tape. To move the entire tape as a unit, drag the middle.



2. Unfixing the position

By default, the tape measure has a fixed position--that is, the position of both ends is the same in all frames. Uncheck the Fixed Position checkbox in its track menu to allow the position to vary independently from frame to frame.

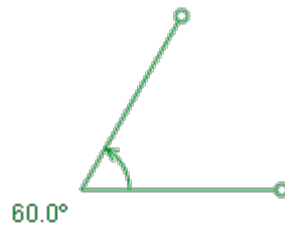
3. Locking the tape measure

Locking the tape measure prevents any changes in its end positions. Lock the tape by turning on the Locked property in its [track menu](#).


Note that if the scale of the video changes, the tape readout will show a different world length even though

the end positions of the tape have not changed.

Protractor

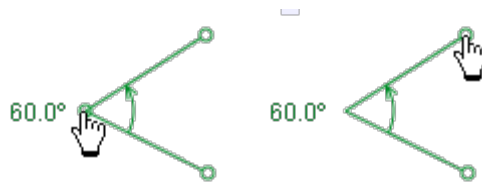


A protractor track is a tool for measuring angular arcs. It has a vertex, two arms, an arc arrow and an angle readout that displays either degrees or radians (see [Setting angle units](#)).

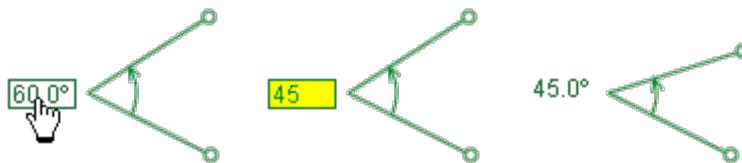
To create a protractor, click the Create button  and choose Measuring Tools|Protractor from the popup menu. Multiple protractors can be created as needed.

1. Measuring an angular arc

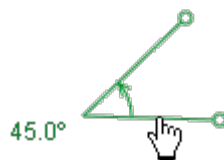
Click and drag the vertex or circular end of either arm to adjust the arms. The arc arrow shows the direction (cw or ccw) of the arc and the angle readout and toolbar angle field display its value (positive if ccw, negative if cw).



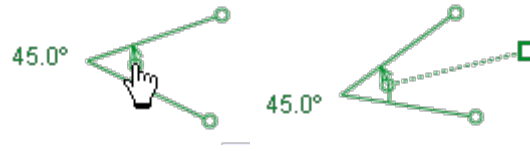
Set the arc to a specific angle by clicking either the angle readout or toolbar field and entering the desired angle.



Drag the center of either arm to move the entire protractor without changing the angle or orientation.



Drag the arc arrow to rotate the entire protractor about its vertex without changing the angular arc. For finer control you can drag away from the vertex--a dashed line continues to connect the drag point to the arc arrow as shown.



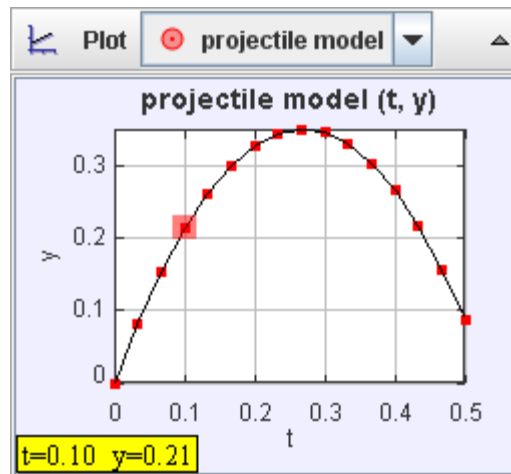
2. Unfixing the position

By default, the protractor has a fixed position--that is, its vertex and arm positions are the same in all frames. Uncheck the Fixed Position checkbox in its track menu to allow these properties to vary independently from frame to frame.

3. Locking the protractor

Locking the protractor prevents it from making any changes to the scale. Lock the protractor by turning on the Locked property in its [track menu](#).

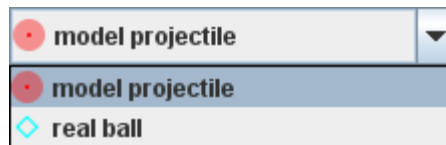
Plot View



The plot view displays plots of a track's data. It has its own toolbar for selecting tracks and displaying multiple plots. The color of the plot markers is the same as that of the selected track. The data point associated with the current video frame or currently selected step is highlighted in the plot and its coordinates are displayed in the lower left corner.

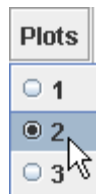
1. Selecting a track

Select the track of interest from the dropdown list on the plot view's toolbar.

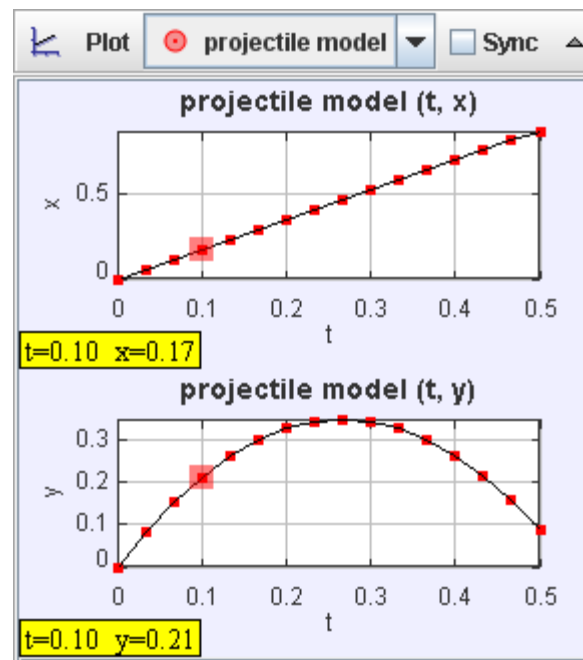


2. Multiple plots and synchronized x-axes

Click the Plots button and choose the number of plots desired. Multiple plots are stacked vertically.



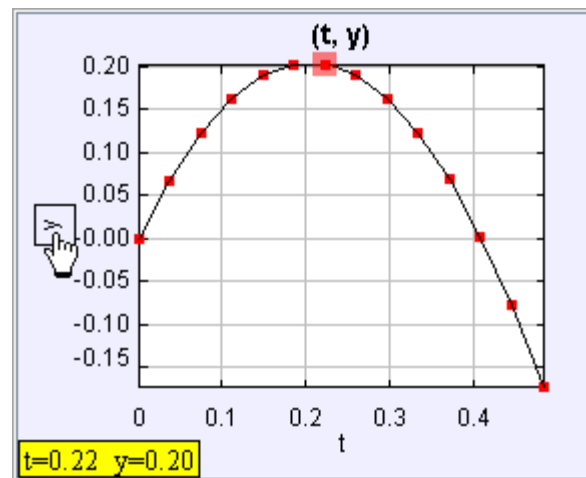
Check the Sync checkbox to synchronize the horizontal axes of the plots so that they all share the same variable and scale. Unchecking this box enables the horizontal variables and scales to be set independently. Vertical variables and scales are always independent.



3. Setting plot axis variables

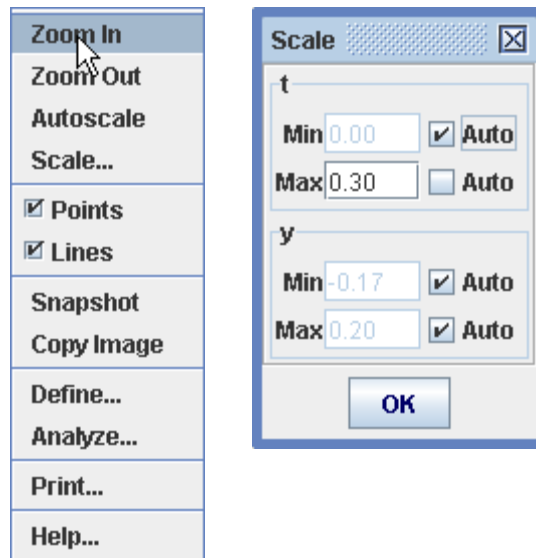
Move the mouse over an axis label until a box appears, then click on the box and choose the desired variable from the popup list.

- ☐ x: position x-component
 - ☒ y: position y-component
 - ☐ r: position magnitude
 - ☐ θ r: position angle
 - ☐ vx: velocity x-component
 - ☐ vy: velocity y-component
 - ☐ v: velocity magnitude
 - ☐ θ v: velocity angle
 - ☐ ax: acceleration x-component
 - ☐ ay: acceleration y-component
 - ☐ a: acceleration magnitude
 - ☐ θ a: acceleration angle
 - ☐ θ : rotation angle
 - ☐ ω : angular velocity
 - ☐ α : angular acceleration
 - ☐ step: step number
 - ☐ frame: frame number
 - ☐ px: momentum x-component
 - ☐ py: momentum y-component
 - ☐ p: momentum magnitude
 - ☐ θ p: momentum angle
 - ☐ K: kinetic energy
- Define...

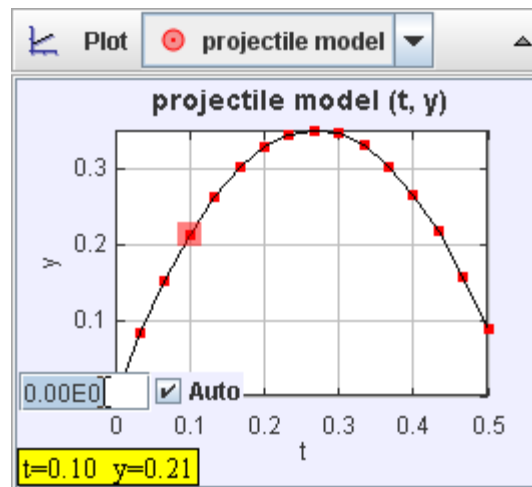


4. Setting the scale

The plot axes autoscale by default. There are several options for setting the horizontal and/or vertical scale manually:

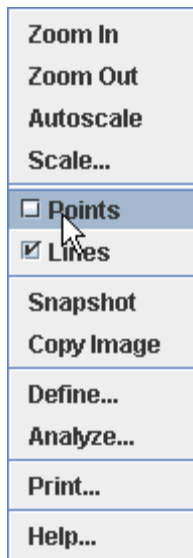


1. Right-drag on the plot to mark a region of interest, then choose Zoom In from the popup menu to zoom in on the marked region. The popup menu also enables you to Zoom Out, Autoscale, or display a Scale dialog for setting limits and/or autoscale properties for both ends of both axes.
2. Move the mouse near the center section of an axis until a double-ended arrow appears, then click and drag the axis to "move" the plot along that axis without zooming.
3. Move the mouse near either end of an axis until a single-ended arrow appears, then click and drag the axis to "zoom" that end while keeping the opposite end unchanged.
4. Hold down the Alt key until a four-way arrow appears, then click and drag to "move" the plot in any direction without zooming.
5. Move the mouse near either end of an axis to display a popup field and checkbox for setting the limit and/or autoscale property for that axis end.



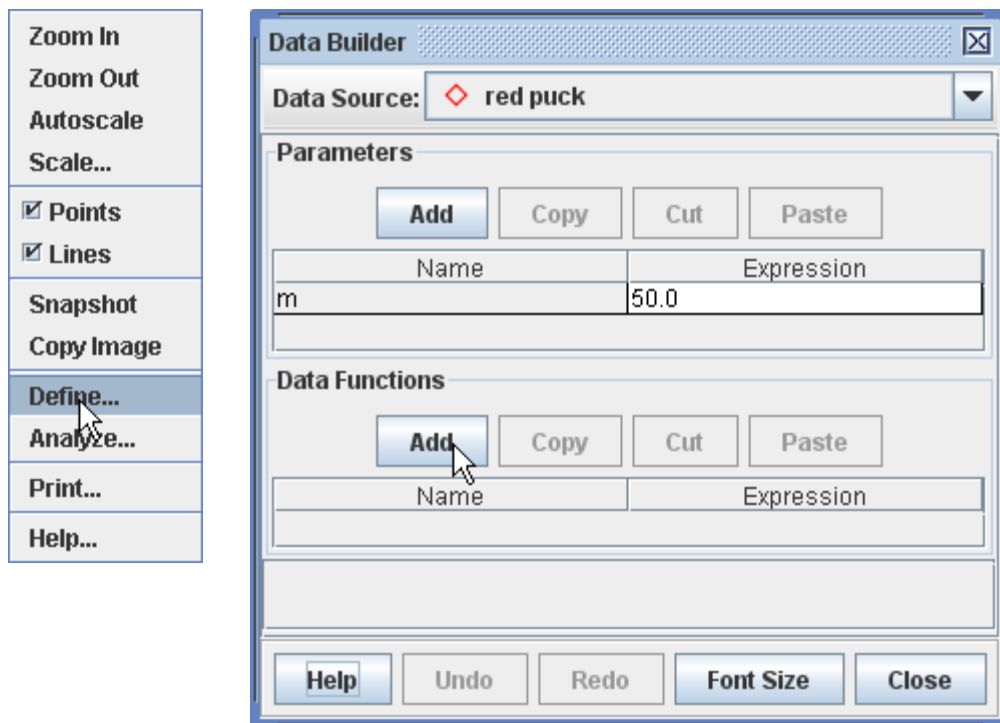
5. Hiding data point and lines

Right-click the plot and uncheck the appropriate box to hide the data points or connecting lines.

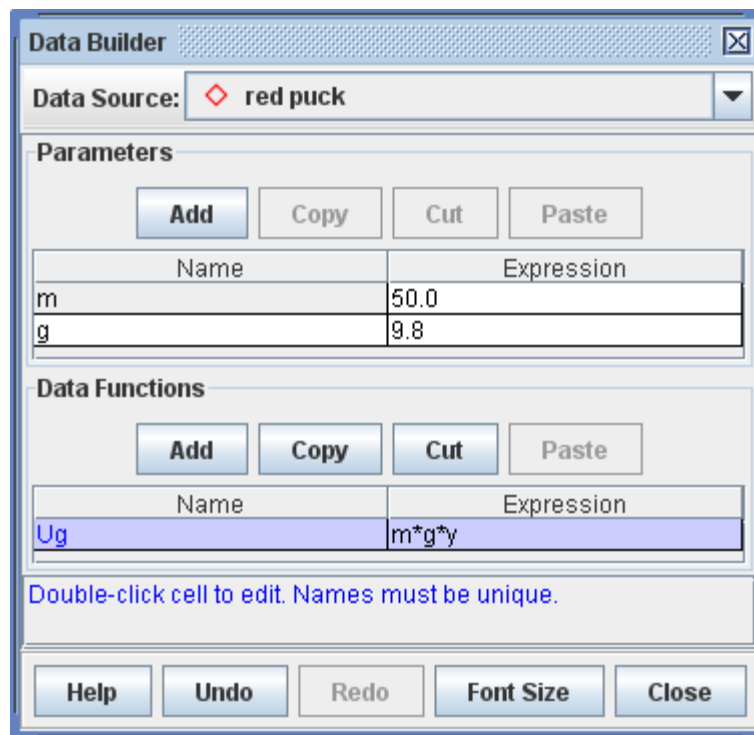


6. Defining new data columns with Data Builder

Right-click a plot and choose Define... to display a Data Builder with which you can define custom variables called data functions for plots and datatables. Click the appropriate Add button to add new data functions or to define parameters for use in function expressions.



Data functions can be virtually any mathematical function of parameters, track-defined data columns, and other data functions.



Functions and parameters are defined by entering expressions that are "parsed" (interpreted) by the OSP parser. The values of parameters are constants while those of functions depend on data variables such as x, y, t, etc. The parser recognizes the following elements:

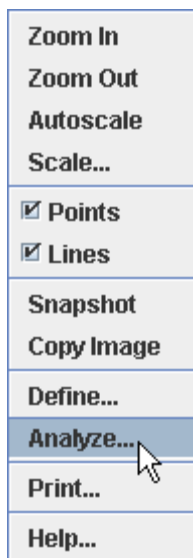
- **Numbers** in decimal or scientific notation (e.g., 1.0E-3)
- **Names** of parameters, functions and other input variables
- **Constants** e and pi
- **Arithmetic operators** + - * / ^
- **Boolean operators** = > < <= >= <> & | !
- **Parentheses** to control order of operation
- **Mathematical functions** shown in Table 1
- **If statements** in the form *if(conditional statement, expression1, expression2)*. Expression1 is evaluated if the conditional statement is true and expression2 is evaluated if it is false. For example, if (x < 0, x^2, -x^2) is a valid function expression.

abs(x)	acos(x)	acosh(x)	asin(x)	asinh(x)	atan(x)	atanh(x)	atan2(x,y)	ceil(x)	cos(x)
cosh(x)	exp(x)	frac(x)	floor(x)	int(x)	log(x)	max(x,y)	min(x,y)	mod(x,y)	random(x)
round(x)	sign(x)	sin(x)	sinh(x)	sqr(x)	sqrt(x)	step(x)	tan(x)	tanh(x)	

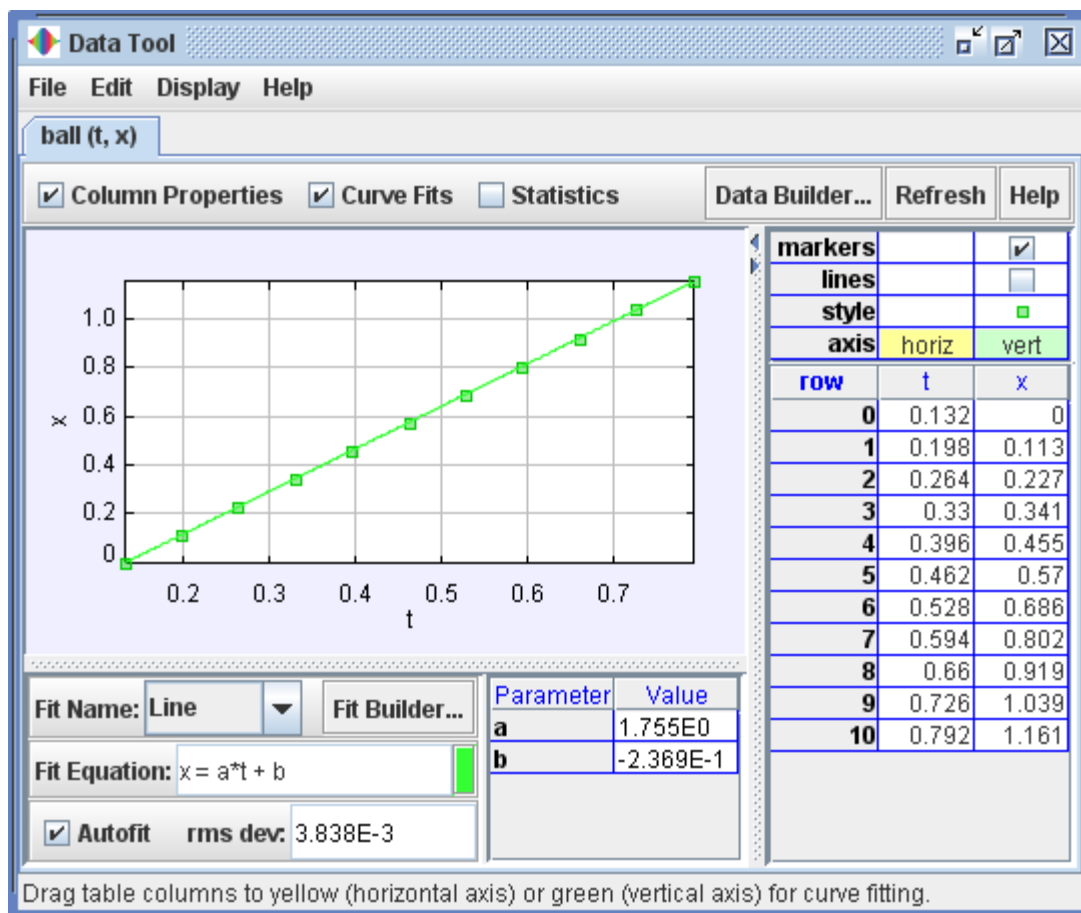
Table 1 Mathematical functions recognized by the OSP Parser

7. Analyzing data with Data Tool


Right-click a plot and choose Analyze... to open its data in the Data Tool for analysis.



The Data Tool provides data analysis including automatic and manual curve fitting of all or any selected subset of the data. For help using Data Tool, open Data Tool and click its Help button.



Datatable View

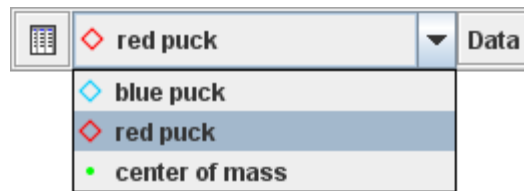


t	x	y
0	0.104	-0.093
0.133	5.226	-0.007
0.267	10.385	0.061
0.4	15.45	0.063
0.534	20.512	0.145
0.667	25.559	0.123
0.801	30.549	0.179
0.934	35.52	0.142

The datatable view displays a table of a track's data. It has its own toolbar for selecting the track and visible data columns. The data displayed in the table can be analyzed with the Data Tool or copied to the clipboard for pasting into a spreadsheet or other application.

1. Selecting a track

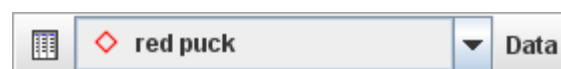
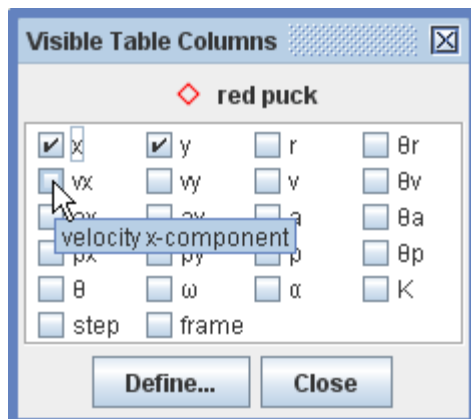
Select a track from the dropdown list on the datatable view's toolbar.



2. Selecting visible data columns

Select the data columns displayed in the table by clicking the Data button and checking those of interest. The time column is always displayed.

Cells for which no data exists are empty. In particular, velocities and accelerations cannot be determined at the beginning, end, or where there are gaps in the position data.



t	x	y	v_x
0	4.178	-21.597	
0.133	7.998	-15.935	28.811
0.267	11.869	-10.387	29.034
0.4	15.748	-4.902	30.806
0.534	20.092	-7.337	32.715
0.667	24.481	-10.499	32.742
0.801	28.832	-13.538	32.537
0.934	33.166	-16.655	

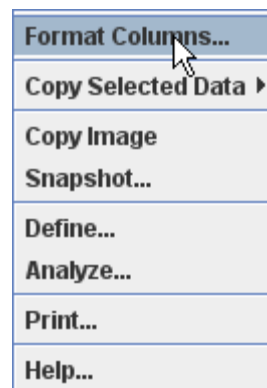
3. Sorting rows

Click a column header to sort rows in ascending order of the data in the clicked column. The sorted column name is displayed in bold font.

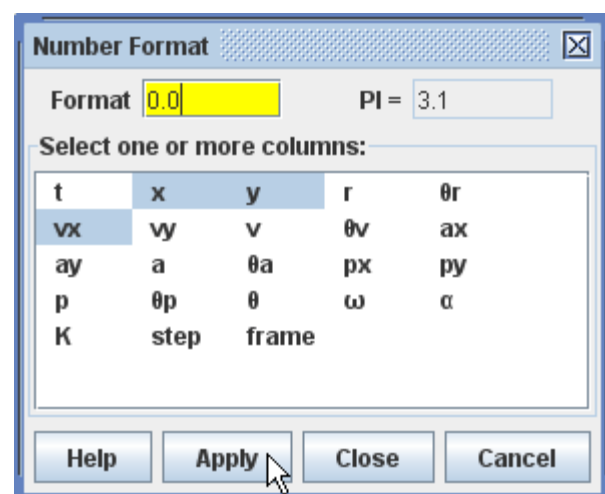
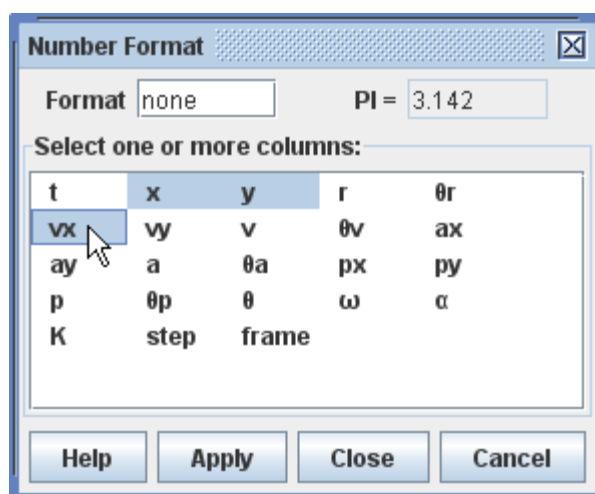
red puck				Data
t	x	y	v _x	
0	4.178	-21.897		
0.934	33.166	-16.655		
0.133	7.998	-15.935	28.811	
0.801	28.832	-13.538	32.537	
0.667	24.481	-10.499	32.742	
0.267	11.869	-10.387	29.034	
0.534	20.092	-7.337	32.715	
0.4	15.748	-4.902	30.806	

4. Formatting data columns

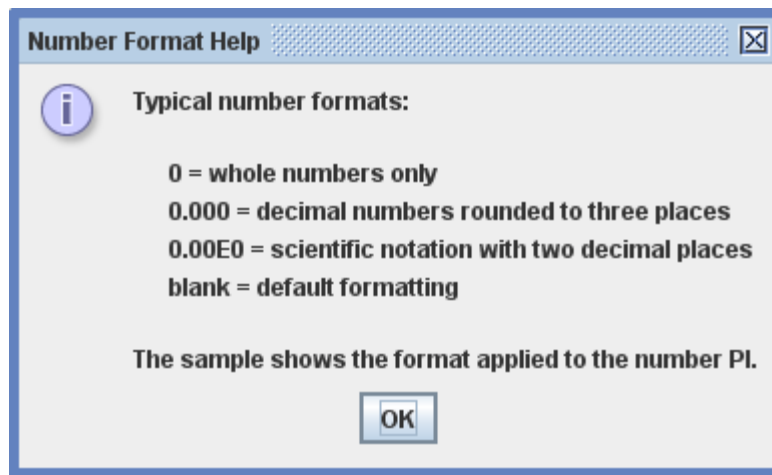
Right-click the data table and select the Format Columns... item from the popup menu to display the Number Format dialog.



In the dialog, select the names of the columns you wish to format. Use the shift and control keys to add or remove names from the selection. Enter the desired format into the format field to apply it to the selected columns. The sample field shows the result of the format applied to the number PI.



Click the Help button to display sample formats.



5. Selecting data cells

Click and drag in the table to select cells. Double-click any cell to select all cells, or double-click a column header to select that column.

Control-click a cell to add or remove that row and column to or from the current selection. Control-click a column header to add or remove that column to or from the current selection.

Shift-click a cell to add that and all intervening rows and columns to the current selection. Shift-click a column header to add that and all intervening columns to the current selection.

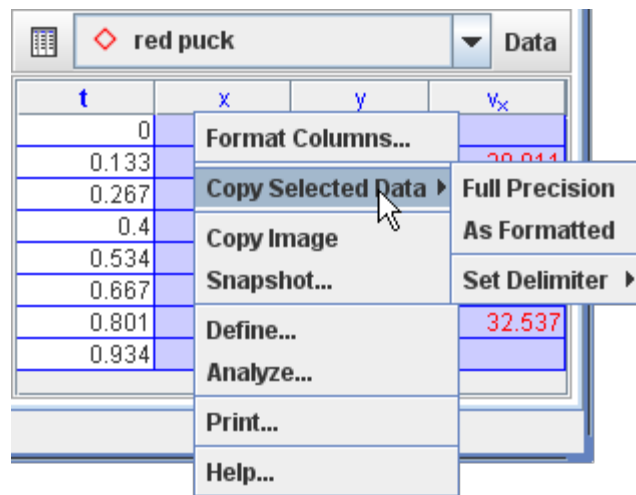
red puck					red puck				
Data					Data				
t	x	y	v _x		t	x	y	v _x	
0	4.178	-21.597			0	4.178	-21.597		
0.133	7.998	-15.935	28.811		0.133	7.998	-15.935	28.811	
0.267	11.869	-10.387	29.034		0.267	11.869	-10.387	29.034	
0.4	15.748	-4.902	30.806		0.4	15.748	-4.902	30.806	
0.534	20.092	-7.337	32.715		0.534	20.092	-7.337	32.715	
0.667	24.481	-10.499	32.742		0.667	24.481	-10.499	32.742	
0.801	28.832	-13.538	32.537		0.801	28.832	-13.538	32.537	
0.934	33.166	-16.655			0.934	33.166	-16.655		

Click the blank area below the data table to deselect all cells.

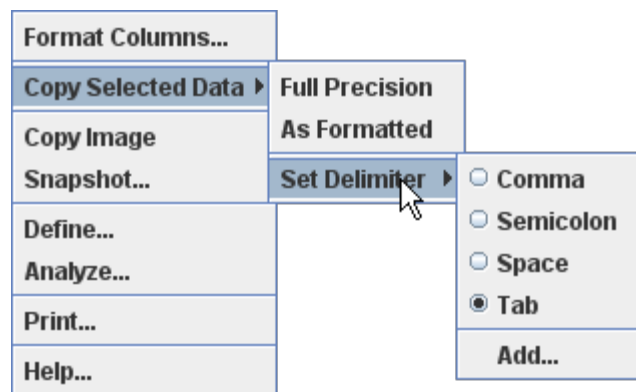
6. Copying data

Right-click the table and select Copy Selected Data from the popup menu to copy the selected cells to the clipboard. On Mac, select one cell, then hold down both the shift and control keys while clicking on a second cell to select the enclosed range and pop up the Copy menu.

Cell values may be copied in full precision scientific notation or using the format displayed in the table.

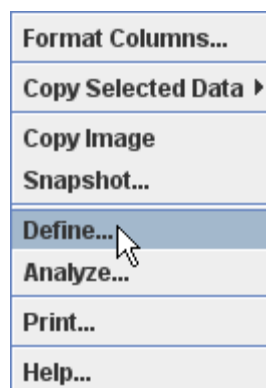


By default, cells are copied as text strings delimited by tabs between columns and line returns between rows. You can change the column delimiter using the Set Delimiter menu as shown.



7. Defining new data columns with Data Builder

Right-click the table and choose Define... to display a Data Builder with which you can define custom variables called data functions for plots and datatables.



Click the appropriate Add button to add new data functions or to define parameters for use in function expressions.

Data Builder [X]

Data Source: ♦ red puck ▼

Parameters

Add Copy Cut Paste

Name	Expression
m	50.0

Data Functions

Add Copy Cut Paste

Name	Expression
------	------------

Help Undo Redo Font Size Close

Data Builder [X]

Data Source: ♦ red puck ▼

Parameters

Add Copy Cut Paste

Name	Expression
m	50.0
g	9.8

Data Functions

Add Copy Cut Paste

Name	Expression
Ug	m*g*y

Double-click cell to edit. Names must be unique.

Help Undo Redo Font Size Close

Data functions can be virtually any mathematical function of parameters, track-defined data columns, and other data functions.

Functions and parameters are defined by entering expressions that are "parsed" (interpreted) by the OSP parser. The values of parameters are constants while those of functions depend on data variables such as x, y, t, etc. The parser recognizes the following elements:

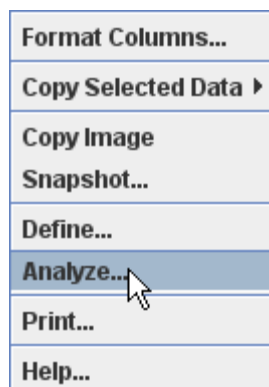
- **Numbers** in decimal or scientific notation (e.g., 1.0E-3)
- **Names** of parameters, functions and other input variables
- **Constants** e and pi
- **Arithmetic operators** + - * / ^
- **Boolean operators** = > < <= >= <> & | !
- **Parentheses** to control order of operation
- **Mathematical functions** shown in Table 1
- **If statements** in the form *if(conditional statement, expression1, expression2)*. Expression1 is evaluated if the conditional statement is true and expression2 is evaluated if it is false. For example, *if (x < 0, x^2, -x^2)* is a valid function expression.

abs(x)	acos(x)	acosh(x)	asin(x)	asinh(x)	atan(x)	atanh(x)	atan2(x,y)	ceil(x)	cos(x)
cosh(x)	exp(x)	frac(x)	floor(x)	int(x)	log(x)	max(x,y)	min(x,y)	mod(x,y)	random(x)
round(x)	sign(x)	sin(x)	sinh(x)	sqr(x)	sqrt(x)	step(x)	tan(x)	tanh(x)	

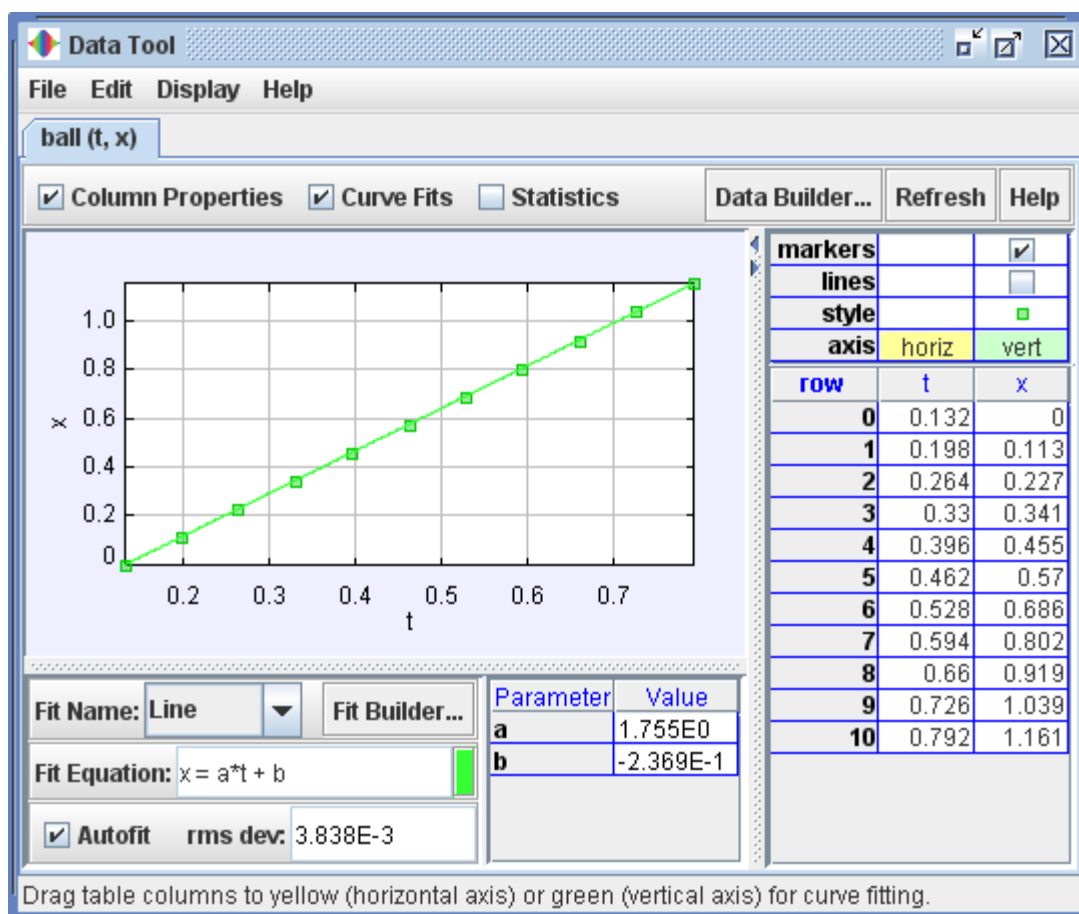
Table 1 Mathematical functions recognized by the OSP Parser

8. Analyzing data with Data Tool

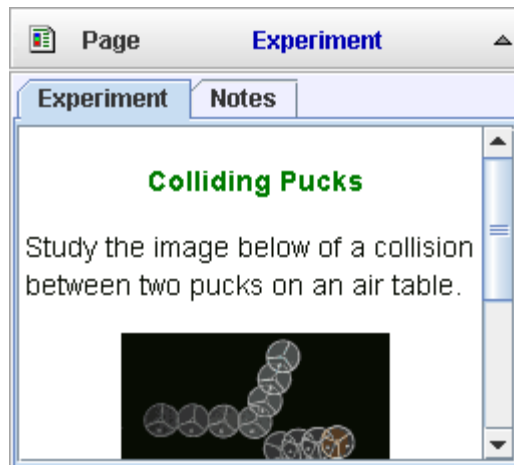
Right-click the table and choose Analyze... to open all visible columns in the Data Tool.



The Data Tool provides statistical analysis including automatic and manual curve fitting of all or any selected subset of the data. For help using Data Tool, open Data Tool and click its Help button.



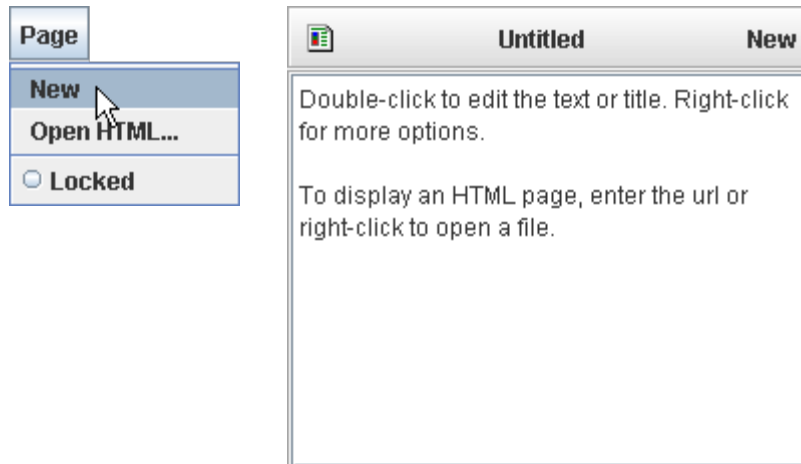
Page View



The page view displays text and html pages. Each page has a title. Multiple pages are organized into tabs.

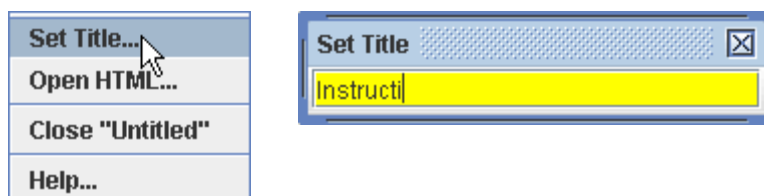
1. Creating a page

Click the Page button to display its menu and select New to create a page. The new page and its title are immediately displayed. By default, the title is "untitled" and the text is a brief set of editing instructions.



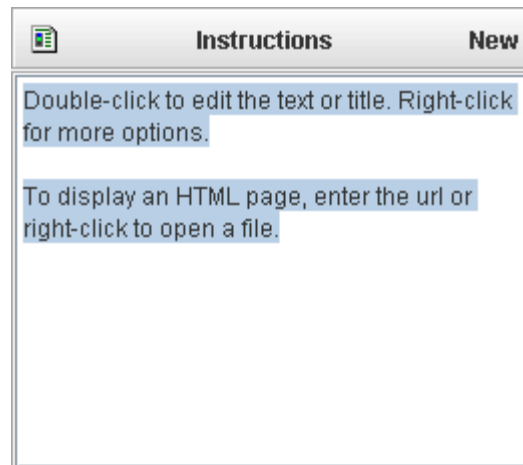
2. Setting the title

To change the title, double-click the current title or right-click the page and choose Set Title... from the popup menu. A dialog box will be displayed with the current title selected in an input field. Type a new title into the field (background will turn yellow while typing) and hit the Enter key.



3. Editing the text

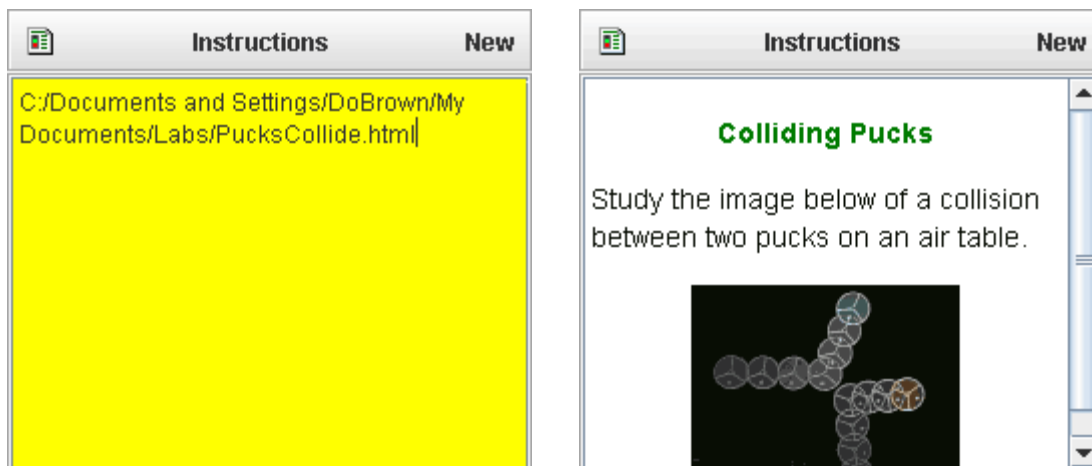
Double-click the page to edit the text. The current text will automatically be selected.



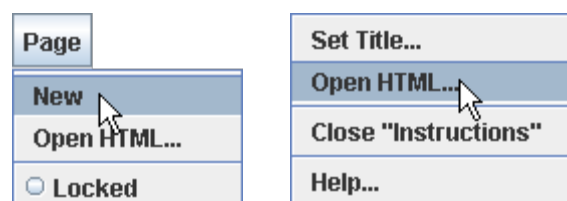
As you edit the text the background will turn yellow to indicate you have unsaved changes. When done making changes, enter the text by hitting shift-Enter (pressing the Enter key while holding down the shift key) or clicking anywhere outside the page. Note: the Enter key alone (without the shift key) does not enter your text but instead starts a new paragraph.

4. Displaying an HTML document

To display an HTML document, enter the path to the document as the page text. The path may point to a file on a local machine or a remote server.

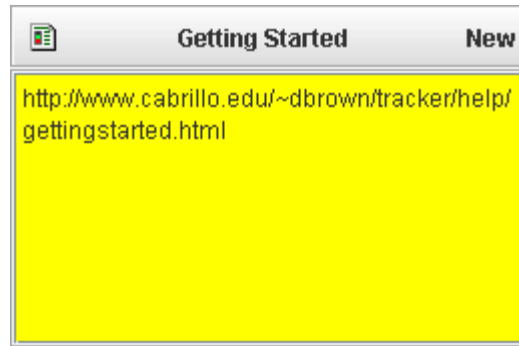


For local files, you can also choose Open HTML... from the Page menu or popup menu, then select the html document with a standard Open File dialog.



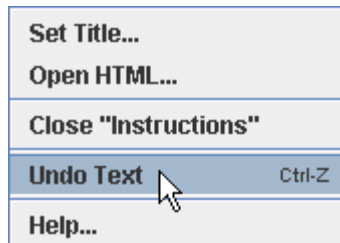
For a file on a remote server, the path must include the url protocol ("http://") as shown below. An easy way

to enter the correct path is to navigate to the file in a web browser, then copy the browser address and paste as the page text.



5. Undo and redo

To undo or redo changes to the text, right-click the page or its title and choose the corresponding item from the popup menu, or use the keyboard shortcuts control-Z (undo) or control-Y (redo). Note: the undo menu item is available only after the text has changed, and the redo item only after undoing a change.



6. Closing a page

To close a page (for example, the "Instructions" page), right-click the page or its title and choose Close "Instructions" from the popup menu.

7. Locking a page

Locking a page prevents changes in its content or title. There are two ways to lock a page:

1. Select Locked in the Page menu. To unlock the page, deselect the same item.
2. Open the [Preferences dialog](#) and uncheck page.edit in the configuration tab. This makes all page views read-only.

Tracker Files

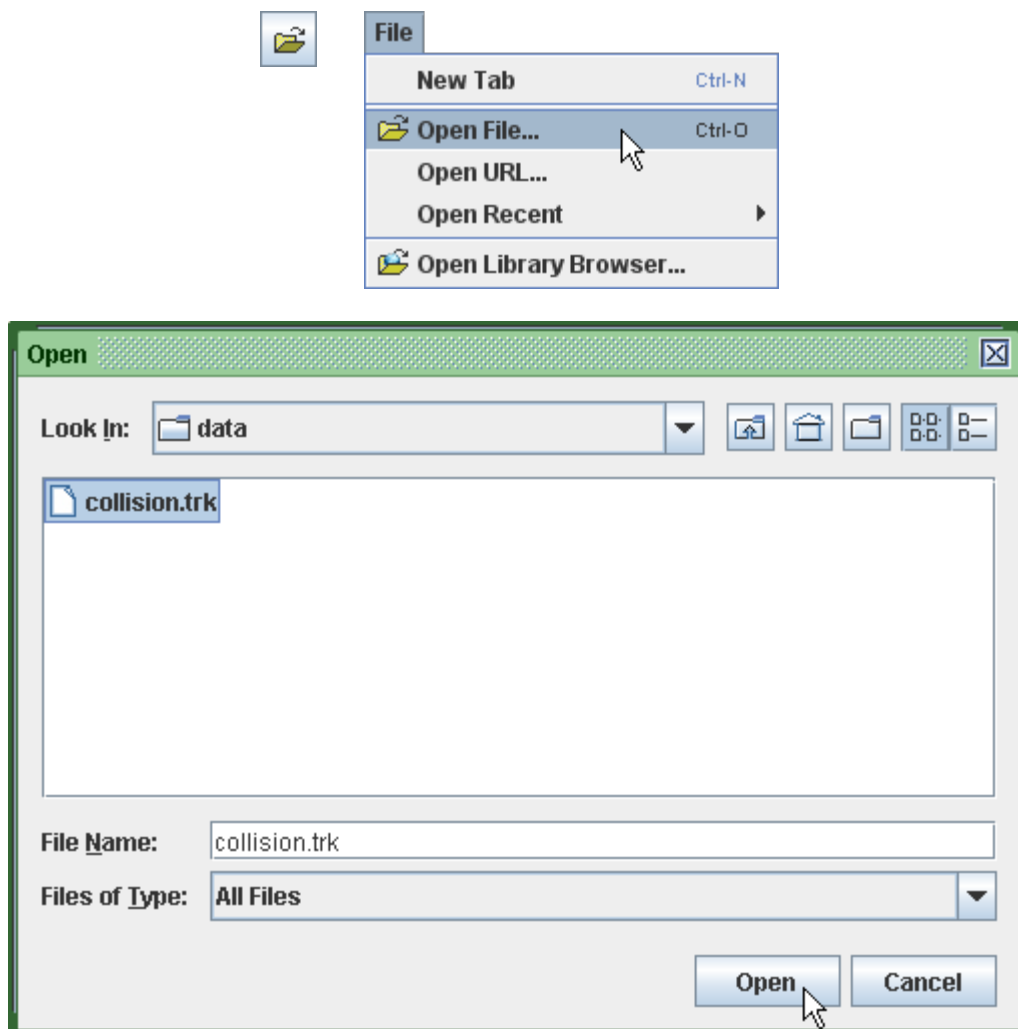
Tracker saves the state of individual tabs (video clip, coordinate system, tracks and views) in xml-based tracker files with the extension ".trk". When a saved tracker file is opened, the saved state is reproduced in a new tab.

You can also save a [tabset](#) that references several tabs (individual tabs must be saved first). The tabset is a separate tracker (.trk) file that, when opened, loads all the tabs at once.

Step positions saved in tracker files are in image (pixel) coordinates, so they are not suitable for direct analysis. To access the world data associated with a track, use a [datatable view](#) or export the data to a [delimited text file](#).

1. Opening a tracker file from a local drive

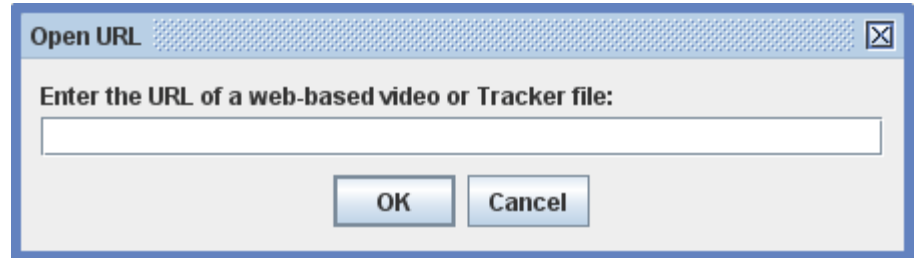
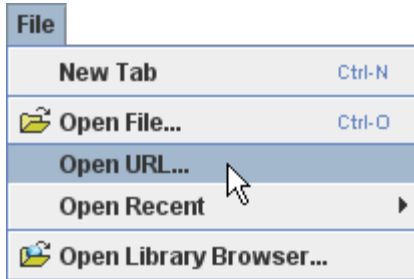
Bring up the open dialog with the Open button or File|Open File menu item, select the desired file, and click Open.



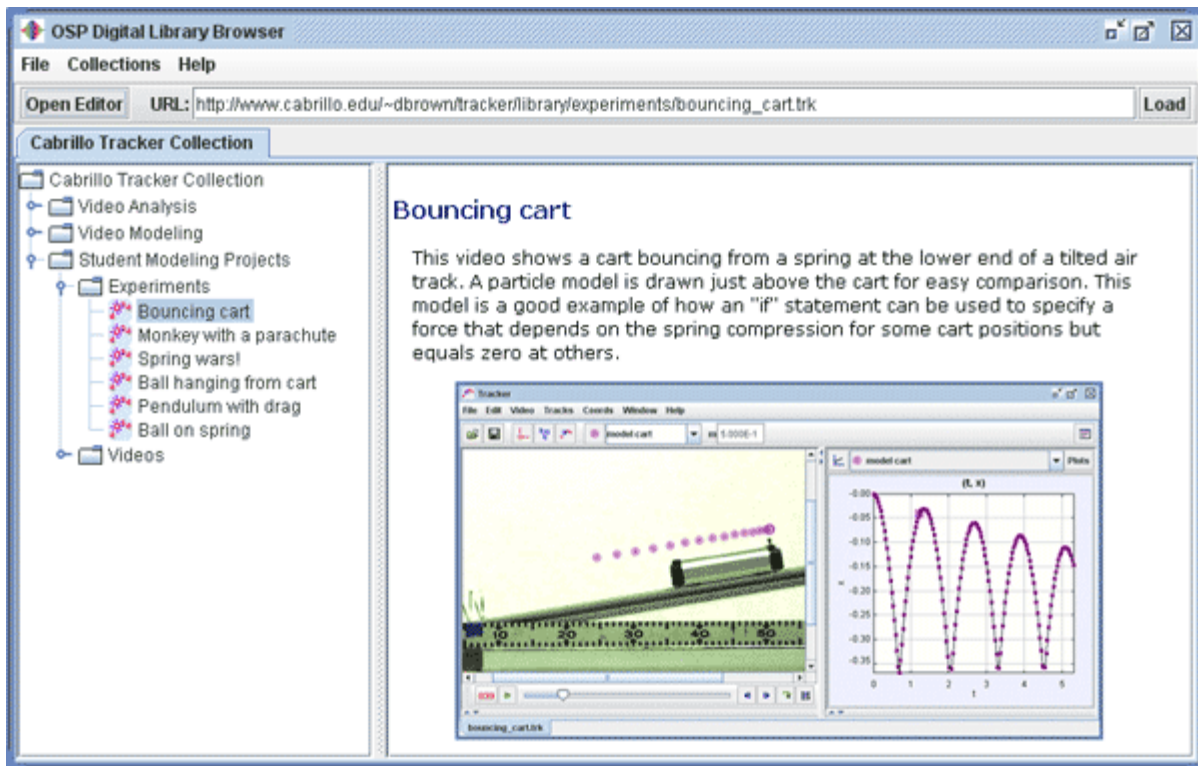
Tracker opens the file in a new tab that displays the file name.

2. Opening a tracker file from the web

Choose the File|Open URL menu item and enter a known URL in the dialog to open a tracker file directly from the web.



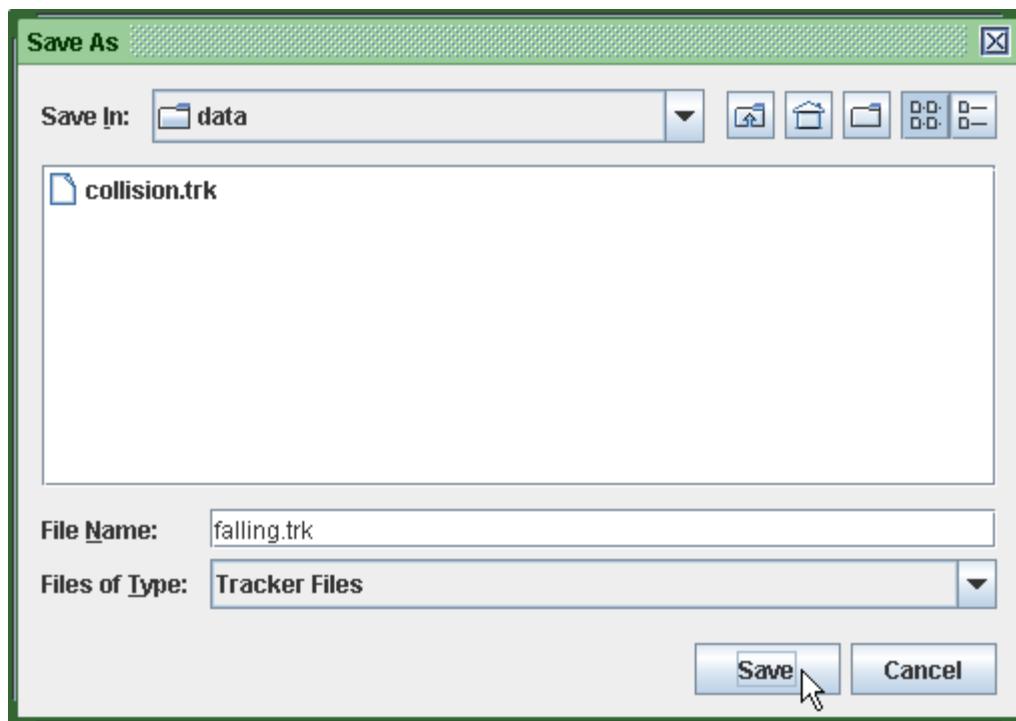
Another option is to open the OSP Digital Library Browser by clicking the Open Library Browser button or choosing the File|Open Library Browser menu item. The library browser enables you to browse and access collections of digital library resources including videos and tracker files. For help using the OSP Digital Library Browser, choose its Help|Library Browser Help menu item.



3. Saving a tab

Save changes to an open tab by clicking the Save button  or File|Save Tab "filename" menu item.

Save a new tracker file by choosing the File|Save Tab As... menu item. Tracker will automatically assign the file a ".trk" extension.

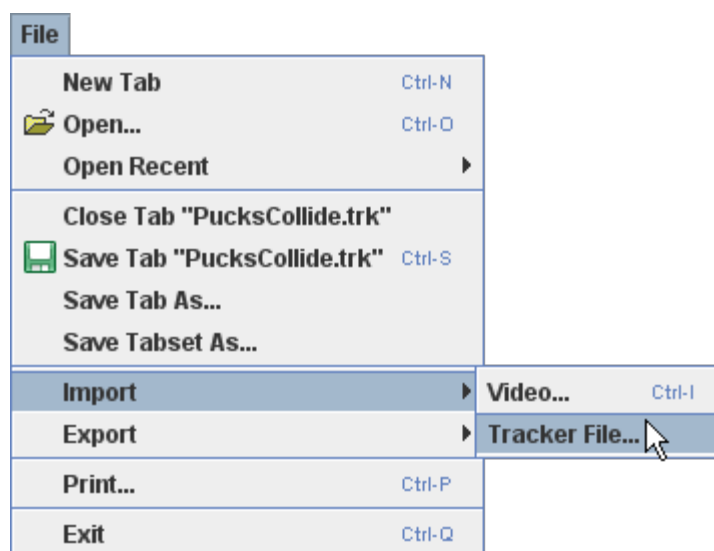


4. Saving a tabset

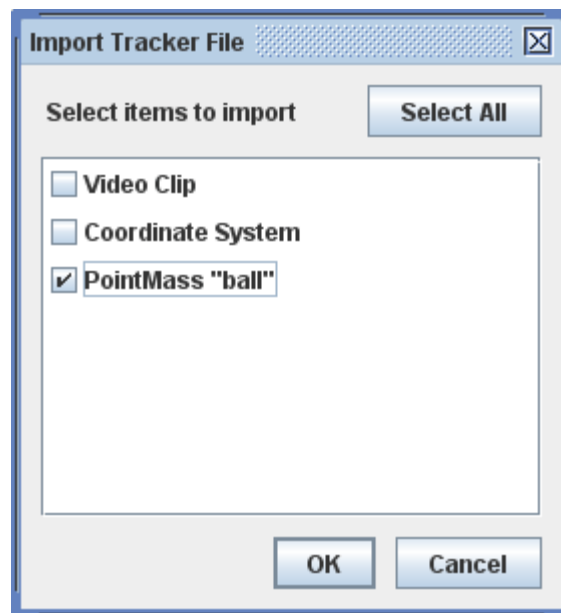
Save a tabset by choosing the File|Save Tabset As... menu item. You will first be prompted to save open tabs that have not previously been saved. All currently open tabs will be included in the tabset tracker file.

5. Importing from a tracker file

Videos, tracks and/or the coordinate system from a tracker file can be imported into an existing tab using the Import|Tracker File menu item from the File menu.



When importing from a tracker file, the available elements are displayed in a dialog that allows the user to select those desired.

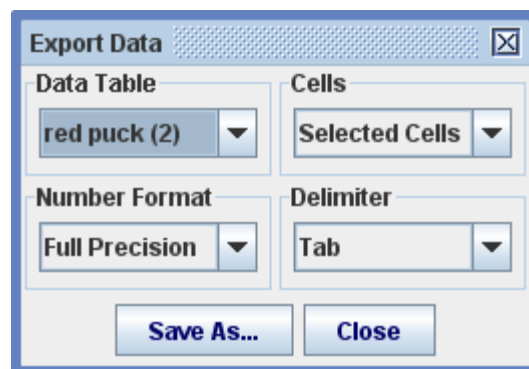


6. Editing a tracker file directly

A tracker file is easily human-read and edited with any text editor. The xml format conforms to the doctype specification defined in osp10.dtd.

7. Saving data in a text file

Save the data displayed in a data table by choosing the Export|Data File... item. This will bring up the Export Data dialog as shown.



In the dialog, select the data table and cells to export, the number format desired (full precision or as formatted in the table), and the delimiter used for separating columns. The file is saved in a plain delimited text format readable by spreadsheets, word processors and many other applications.